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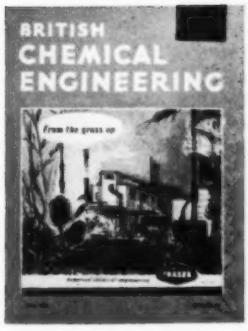

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BRITISH CHEMICAL ENGINEERING

DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Expansion at Imperial College

OFFICIALLY opened by Her Majesty, Queen Elizabeth the Queen Mother, Chancellor of the University of London, on May 28, the new Roderic Hill building of Imperial College provides the College's chemical engineering department with an additional 30,000 sq. ft. of working space. Besides increasing the department's efficiency, the new extension is expected to enable the number of students to be augmented from the present 150 (undergraduate) and 100 (post graduate) to, respectively, 170 and 195. The proposed reversal of the present ratio of students indicates that advantage will be taken of the improved facilities to further the department's traditional policy of specially fostering research work. The new accommodation includes a much wanted library with adequate facilities for private study: it commemorates Sir Alfred Egerton, whose collected works together with those of Professor Hinchley it contains. Also provided in the new building are a lecture theatre, tutorial rooms, staff offices, teaching and research laboratories, workshop and other technical facilities. The expansion of the department is not complete and further building will have to be undertaken in the future if chemical engineering, a subject which was first taught systematically at the college in the 1880s—under Armstrong's lead—is to be catered for adequately. The department now has a staff of about 50, of whom about half are academic and half technical and administrative. The Roderic Hill building occupies a site formerly known as Rectors lawn. It is built and furnished in a simple, efficient and dignified style, and it creates an atmosphere markedly different from that of its present neighbours. A special feature of the department's work is the study of technologies relating to high pressure, low temperature, and fluid kinetics. As the recently-published quinquennial report of the department points out, the volume of this work recently has increased considerably, and especially in the field of high-speed kinetics. Study at present being undertaken includes the examination of the flow of friable particles through nozzles with a view to effecting disintegration particularly in relation to the size reduction of coal.

I.C.I. Developments

MORE than £12 million were spent by I.C.I. on research and development in 1956, and this allocation, they claim, represents a proportion of turnover, 3.1%, similar to that of the "more progressive" American chemical companies. About 40% of the expenditure was directed towards improving products and processes and a further 40% to discovering and developing new ones. Equipment commissioned during the year included a new plant started by the alkali division for making Winnofil, a special form of calcium carbonate used as a filler in rubber. The general chemicals division brought into operation an extension to their vinyl chloride plant and a large plant for chlorobenzene. Production of isocyanates that form the basis of flexible or rigid foams, on a pilot plant scale during 1956, has been increased recently by the commissioning of a much larger plant. Butakon, developed during the year by the plastics division, is now being produced at the rate of 10,000 tons a year at a plant recently started at Wilton. Notable products marketed during the year included the range of new dyestuffs which are able to unite with molecules of textile fibres. The most promising new product in the pharmaceutical division is Fluothane, a fluorinated hydrocarbon anaesthetic. Despite a record volume of sales, this division had a "difficult" year: it is noteworthy that the division spent 11.6% of its turnover on research and development. Among equipment in course of erection overseas are polythene plants in Australia and India, and a commercial explosives plant in India. Canadian Industries Ltd. expect their new $9-million ammonia plant to be ready for operation this year. I.C.I.'s sales for the year in value and volume were a record. The value was £435 million compared with £411 million in 1955, also a record. The consolidated sales were up by 5.9% over the previous year's figures; in 1955, however, the increase over 1954 was 16.7%.

Niobium in Engineering

THAT the symposium on the metallurgy of niobium recently held in London, under the auspices of the Institute of Metals, was deemed to be necessary itself indicates the potentialities of this element as an engineering material of construction in nuclear processes. The high temperatures which exist in the fission zone of nuclear reactors, for example, rule out the use of more conventional materials of construction, and emphasise that one important property which a material for this use must possess is good mechanical properties at elevated temperatures. A material used for fuel canning must have a high thermal conductivity to allow effective heat transfer to the coolant stream, and, in some kinds of reactor, a good strength at elevated temperatures to restrain the expansion of the fuel element. Moreover, where sodium is used as the heat transfer medium the canning material must be compatible with molten sodium. Niobium, of melting point well over 2000°C, has the requisite properties for use as a canning material, and considerable attention has been paid to its economic production. Much study has also been directed to its technology in order to obtain a high degree of purity upon which many of its advantages depend. As a result, niobium can now be obtained with much greater ductility than previously. The true value of the metal lies in the combination of its properties. Niobium has, for example, a greater resistance to tearing and splitting than most other metals when deep drawn. It has also excellent corrosion resisting properties. It will resist satisfactorily all the mineral acids usually employed. It is possible, therefore, that the metal can be used in sheet form as a cladding material for chemical vessels handling corrosive reagents, and it is quite likely that, as the extraction processes develop, niobium will supplant tantalum—a metal with which it occurs in nature.

Atomic Breeding

TO a country like Britain, limited as it is in natural power resources, whose mineral reserves of energy are dwindling and more difficult to win, the development of nuclear energy is essential to its expanding economy. There are a number of problems affecting the future of atomic power, central among them being the development of the process known as atomic breeding. This process has a direct bearing upon the economics of nuclear power and the supply of nuclear fuels. Of these, but three are known at present, U235, PU239, which is derived from natural uranium, and, finally, U233, derived from natural thorium. The only natural occurring fuel is U235, which occurs to the extent of 1 part in 140 of natural uranium. PU239 and U233 have to be produced by man-made transmutations.

In a nuclear reactor when U235 breaks down through absorbing a slow neutron it yields, apart from atoms of lower atomic number, gamma radiation and fast neutrons. Actually two-and-a-half neutrons are produced per fission but the useful number is much less than this because some are lost in non-useful absorptions. For example, one neutron has to replace that used in the original U235 fission and if U238 is present in the reactor another neutron will be captured by an atom of this element to give an atom of fissile plutonium. Since the number of available neutrons per fission is slightly in excess of 1— the maximum lies somewhere between 1.1 and 1.5— there is a real possibility of producing more fissile material from a reactor than is fed to it in the first place. The fast reactor at Dounreay now nearing completion will be one of the instruments by which this process will be developed to commercial proportions (see page 378, this issue).

Thermonuclear Power

The results of some preliminary work that has been done at Harwell on thermonuclear reactions have just been published in *The Proceedings of the Physical Society* (1957, Vol. 70, Pt. 1, No. 445 B). Included is the study of W. B. Thompson. In this he considers which is the most promising of a number of exoergic thermonuclear reactions involving the fusion of deuterium or tritium atoms. He concludes that the most hopeful reaction is the tritium+deuterium reaction, the reaction probability of which is at least ten times greater than that of any other for temperatures between 10^5 and 10^9 degrees. The deuterium +deuterium reaction, although proceeding more slowly, uses only naturally occurring material, and if all the charged reaction products can be made to take part in the thermonuclear process the total energy released per reaction is 21.6 MeV, which is greater than the 17.6 MeV produced by tritium+deuterium alone. At temperatures of less than 10^9 degrees only these reactions are significant, although this may not hold at higher temperatures.

Middlesbrough Coking Plant

A NEW coking plant said to be the largest ever built as a single unit in Britain is now in operation at Dorman Long's site at South Bank, Middlesbrough. Built by Simon-Carves to provide metallurgical coke for the new Clay Lane blast furnaces, it comprises 150 ovens with a weekly throughput of 25,000 tons of coal; coal and coke handling equipment; and by-product plant. The installation is arranged so that it can be duplicated. The coke ovens are of the twin-flue compound underjet type for heating by coke-oven or blast-furnace gas, and they are divided into two batteries of 75, each draughted by a 280 ft. chimney. For ease of rebuilding, each battery is subdivided into five blocks of 15 ovens. Over the sole the ovens' dimension is 44 ft. 7 in. cold, and the chamber height is 14 ft. 9 in. cold. Each charge weighs 19.26 tons wet, and the gross coking time is about 19.2 hours. The by-product plant, which handles the gas from the whole of the coal throughput, is of orthodox design and embodies the indirect ammonia recovery system.

Coking under Nationalisation

THE output of the National Coal Board's coking plant in the ten years since nationalisation has increased from 5.95 million tons to 7.2 million tons, and nearly 30% of the coke produced in 1956 came from plant installed since 1947. Some of the 55 plants taken over by the Board were modern and efficient but many were approaching the end of their useful lives and others were too small or otherwise inefficient. The major programme of construction which, therefore, faced the Board at its outset has now been largely completed; only two new plants—Murton in the Durham division, and Cwm in the South Western division—and one major reconstruction—at Glasshoughton, North Eastern division, remain to be finished and these should be completed by the end of 1958. The capital expenditure so far is £38 million. The Board, the largest single producers of crude benzole in the country, made 28.0 million gallons in 1956, compared with 25.7 million in 1955. Their policy is to refine as much of it as possible themselves. Of the 28 refineries taken over on nationalisation 12 have been closed, but large new central refineries have been added—at Nantgarw in 1951, Avenue in 1955, and Manvers Main (with a capacity of six million gallons a year) in 1956. In their report for 1956 just published, the Board state that the greatest change in the benzole market in the past ten years has been a considerable increase in demand for industrial fractions, as opposed to motor benzole: during this time their production of the pure product has increased tenfold.

The Board also produce more crude tar than any other single maker in the country. Between 1947 and 1956, their output rose from 320,000 tons to over 400,000 tons. The quantity distilled has risen by 50% to 158,000 tons in 1956. Last year two new batteries of ovens went into production at the Phurnacite smokeless fuel plant at Aberaman, and this is now producing at the rate of 640,000 tons annually. A pilot plant for underground gasification of coal for use in generating electricity which will be constructed at Newman Spinney, near Chesterfield, is due to come into operation towards the end of 1958.

New Fatty-Acids Plant

WITH the commissioning recently of a second Emersol plant, costing about £370,000, Price's of Bromborough are now producing all of their stearine and oleine by this solvent-extraction procedure. The sole use of the process, which is continuous and automatically controlled to fine limits, is enabling the fatty acids to be made in improved quantity and quality. The new unit has been constructed under the direction of Blaw-Knox of Pittsburgh, but the contract for the mechanical construction was sub-let to Matthew Hall & Co. Ltd. of London. The process is based on the different solubilities of fatty acids in methanol at a suitably low temperature, and it centres round the operation of the crystalliser, an unusual piece of equipment. Made by the Buflovak Equipment division of Blaw-Knox it consists of a bank of jacketed tubes chilled with methanol, through which passes slowly, in series, a methanol solution of mixed fatty acids and a crystal promoter. Each tube contains a chain-driven rotating scraper which assists the formation of uniform crystals of stearine and promotes heat transfer. The

oleines remain in solution. The chilled slurry is then pumped for the second special stage—vacuum filtration at reduced temperature. The Feinc drum string-discharge filter, made by Stockdale, is completely enclosed in a metal hood for containing the methanol vapours, and the whole equipment is housed in a cold room chilled by an atmosphere cooler. Achievement of great heat economy and the almost complete recovery of the solvent are features of the separation process which make it, it is said, very economical to operate. All instruments and gauges are located at a central control panel, and although the plant can be operated by one man, two usually are employed for reasons of safety. Stringent precautions have been taken to avoid fire and health hazards due to methanol vapour. The new plant enables six men to do the work of 80 formerly employed on the old pressing process, but by consultation with the trade unions a formula was found for making smoothly this adjustment in labour.

Fine Particle Measurement

THROUGH the absence of a simple, rapid or cheap method of fine particle measurement many industrial processes involving the production of powders have to be undertaken without adequate control. An electron microscope, adsorption methods or permeability measurements of powdered beds are sometimes used for fine particle measurement, and simpler tests, more limited in usefulness, are the bulk-density and tinting strength tests. All of these tests have their limitations especially when applied to particles smaller than one micron. For some methods no theory has yet been developed which will permit their use with any promise of reliability. H. E. Rose (*Journal of Applied Chemistry*, 1957, 7, 244) describes an optical method which depends upon a relation between particle size and reflectivity and requires only a simple and inexpensive piece of apparatus. So far particles having extremely low non-selective reflectivity ("black" particles) have been investigated, and the substances have included coals, carbon black and tungsten metal. The method is being extended, however, to selective reflecting powders ("coloured" powders). The results for black powders show that reflectivity is proportional to the mean particle diameter, raised to a power characteristic of the range of particles. An outstanding advantage of the method is that it will allow particles in a tablet or pellet to be determined. Dr. Rose suggests that all that may be necessary to determine how some comminution processes are progressing is a comparison of powder reflectivity against standard samples.

Particle Size and Catalyst Activity

R. T. BURKE and others have discussed (*J. App. Chem.*, 1957, 7, 105) the effect of catalyst particle size on the rate of hydrogenation of benzene to cyclohexane. They found that catalyst activity measured in terms of the rate constant increased directly with the apparent outer surface area until a point was reached where further subdivision produced no evident improvement. They show that for a nickel oxide catalyst supported on silica gel the maximum activity occurred with particles between 80 and 100 mesh. For smaller particles the activity remained constant. This is in contrast with experience of homogeneous catalysts as, for example, tungsten powder, where subdivision produces a steady increase in activity. The explanation appears to be that with the non-homogeneous catalysts a point is reached where all catalytic material on the supporting base is equally accessible to the reacting chemicals. In fact it seems probable that a saturation effect occurs and all the area available is covered by the catalyst.

Clean Air Conference

Sir: My attention has been called to the summary of the Conference organised by the Institution of Mechanical Engineers on Clean Air, published in your May issue. On p. 257 you summarise a contribution which I made to the discussion on the paper by Dr. Forrest and Mr. Lowe. I rather feel that the summary given does not convey the main point I made in my remarks, and I should be glad if you could find space to publish the following amplification.

The point I made was that with a combined cyclone-precipitator plant with cyclic rapping, and with the gas-flow shut off in the section being rapped, the dust deposition rate adjacent to the stack would be only 7% of the figure for a plant equipped with normal precipitators rapping continuously. Further, if the rapping cycle were properly chosen a further reduction in emission would occur, leading to a dust deposition rate of only 5% of that experienced from the normal precipitation plant.

Yours faithfully,

C. J. Stairmand.

Billingham Division,
Imperial Chemical Industries, Ltd.

N.P.L. Open Days

A SIMPLE device which can quickly furnish the approximate value for the thermal conductivity of any solid which has a hard smooth surface was one of the exhibits demonstrated at the National Physical Laboratory during its annual Open Days held recently. The device shown held a small phosphor-bronze ball-bearing which was heated to a constant temperature, and was brought into contact with a test surface. Observations were then made of its rate of cooling. This rate depends on the applied pressure and the nature of the surface, but if calibrations are made for a material of known thermal conductivity, the thermal conductivities of a wide range of other solids, metallic and non-metallic, can be evaluated by comparison. In practice, thermocouples, differentially connected, are used for measuring the temperature of two similarly mounted ball-bearings, one of which makes contact with the test surface. The consequent cooling need be followed for a period of only 10 seconds. The method can be extended to the study of surface conditions and the measurement of foil thicknesses. A radial heat-flow apparatus, which was shown, has been used in the Laboratory to determine the thermal conductivities of aggressive and hygroscopic liquids and some of the results obtained are arresting. They show, for example, that contrary to usual assumptions the thermal conductivity of calcium chloride brine increases with increasing concentration of the salt. In work on the establishment of standards for measuring high pressures, the physics division have developed a new method for determining accurately the changes in the effective area of a piston under high pressure. It depends on a principle of similarity between the distortions of piston-cylinder units of the same size but made of materials of different elasticities. So far, the studies have covered pressures up to 3000 atmospheres.

Cold Grinding

GRINDING is a somewhat neglected unit operation and developments in this field are always of interest. Some years ago the American Linde Products Inc. conducted some work on grinding in which the feed to a mill was cooled by liquid nitrogen in a specially designed exchanger. Work along similar lines has since been carried out by British Oxygen Research and Development Ltd. The work has been concentrated upon plastic materials such as polythene and nylon, materials which when ground in the ordinary way generate sufficient heat to cause molecular degradation. This process, or a modification of it, using a cheaper source of cold than liquid nitrogen, for example liquid CO_2, might be used for other materials which are difficult to grind at ambient temperatures. For example, materials such as gammexane or DDT clog the mills, ducting, etc., due to their softening properties and, therefore, any measure which will avoid such occurrences would be more than welcome. It is doubtful, however, whether liquid nitrogen would be a proposition in instances like this since the stated cost for grinding nylon is about one shilling a pound of material ground. It would be valuable to have an account of this work, particularly in view of the claim that an eightfold increase in output is obtained from the same mill when liquid nitrogen is employed. One gathers that the cost of nitrogen is offset by the power saving and the increased output.

At the other end of the scale is the use of the electric arc as described recently in a series of papers to the American Electro-Chemical Society. Production of particles well below 1 micron has been achieved.

Ceramics and Corrosion

IN the British Non-Ferrous Research Association's recent report, a short account is given of investigations of interest to chemical and process engineers. On the processing side a short reference is given to methods of removing small amounts of lead and tin from molten copper. A process has been worked out which results in much smaller copper losses than are incurred in the conventional methods of refining. The properties of refractories for furnace linings, a common source of trouble in industries employing combustion, have also been under investigation. Tests carried out on a small scale have suggested better refractories than those currently employed in furnaces like the low frequency induction furnaces used for melting cupro-nickels. As a result, full-scale trials are being carried out to test the recommendations of the Association.

Corrosion is another subject which is continuously under examination. For some time now work has been carried out continuously on the corrosion of condenser and heat exchanger tubes, especially where the cooling medium has been a badly polluted water. As a result of the investigations new materials have been found which offer very much greater resistance to corrosion by waters containing hydrogen sulphide.

The report also dealt with stress corrosion as applied to light alloys. Two lines of approach have been followed to tackle this problem. In the first place protective coatings have been tried and, in the second, attempts have been made to modify alloys in order to improve their intrinsic resistance to this form of attack. Success has been achieved with both approaches but, of the two, the report advises that the latter is the better one to adopt. So far improvements in stress corrosion resistance have been made at the expense of the mechanical strength of the alloy and methods of treatment are being sought to preserve it while, at the same time, conferring resistance to stress corrosion.

Industry and Technical Progress

THAT British industry is not universally backward in scientific matters, although there is a great range from the best to the worst firms and "parochialism" exists in large tracts of the industry, are some of the conclusions arrived at by the committee appointed by the British Association in 1952 to study the problems of speeding the industrial application of the results of scientific research. The committee has been supported by the Royal Society of Arts, the Nuffield Foundation and the United States' Conditional Aid Programme, and its report, written by Prof. C. F. Carter, Queens University, Belfast (chairman) and Prof. B. R. Williams, University College of North Staffordshire (secretary) has just been published.* No easy solution to the problems was expected, and the committee emphasise that no single measure like remission of taxation, cutting of red tape, or adoption of some particular form or size of industrial organisation will suffice to open the way to a flood of new applications of science. Progressiveness in science and technology is not an optional extra which a firm can add to its existing qualities, but an expression of its general attitude and efficiency of management. Moreover, many applications of science require the co-ordinated advance of a whole chain of firms. Behind the whole problem stands the question of the supply of able minds—managers, scientists, and technologists, and the committee was satisfied neither with the effectiveness of the British educational system in its work of selection and training, nor with the distribution of trained talent between industries and between firms. In the communication of the results of research, however, great importance is laid on the "scientific middleman"—the research association, the technical journalist, the salesman with a scientific background, the travelling advisory officer. Firms which do not receive knowledge direct through scientists on their staff are not necessarily rendered unreceptive; they may be highly receptive, it is suggested, at the level of the technical journal. (* Oxford University Press. 25s.)

S.C.I. Chemical Engineers

THE general effect so far of the work of the Industrial Fund for the Advancement of Scientific Education is that there is no school of importance now which is not "absolutely thinking of science," said Sir Hugh Beaver, chairman of the Fund, at the annual dinner of the chemical engineering group of the Society of Chemical Industry, in London recently. The Fund's work had created an entirely different attitude of mind on the part of a large number of masters. All of the masters realised that this was a generous effort on the part of industry, and they felt they had been given a great opportunity. The Fund's Committee had accomplished a very small part of what had to be done in this country, and there was nothing of charity about its work. The Fund was concerned with the development of science in every direction and the production of scientists, not only for British manufacturing industries, but for administration and the running of the country. It was the original intention that the work was to be limited to boys' schools, but it had been decided later to include girls' schools. Places for women scientists in industry must be found, Sir Hugh said.

After dinner the chairman (Mr. George Brearley) made a presentation of silver tankards to Mr. R. C. Odams (immediate past-secretary) and to Dr. J. B. Brennan for their work on behalf of the group. The honorary officers of the group for 1957-58 are: *Chairman*, Mr. R. F. Stewart; *Treasurer*, Mr. F. A. Greene; *Secretary*, Mr. J. L. Sweeten; *Editor*, Mr. D. M. Wilson; *Recorder*, Mr. H. W. Thorp.

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The Heart of the Matter

OVER forty years ago, in the columns of *Nature*, Lord Rayleigh could write: "I have often been impressed by the scanty attention paid even by original workers in physics to the great principles of similitude." Today, while the application of these principles to practical problems is not by any means as wide as their usefulness merits, there is a powerful trend—and one which will have a greater influence in the future—in the direction of their wider application. For this reason, the criticism by Lord Rayleigh, which five years ago J. H. Rushton thought should be readdressed to chemical engineers, no longer holds true. The recent scale-up conference (see pages 374-377) will give impetus to the scientific methods that Lord Rayleigh valued. Moreover, the chances of their wider recognition are the better in view of the process of refinement through which chemical engineering is passing. As the benefits of similarity and model techniques become more widely known, so will the desire to use and develop them grow.

Since scale-up may be said to be at the very heart of chemical engineering, a wider appreciation and use of scientific methods for this essential process was certain to arrive. Progress has been slow for a combination of reasons; engineering has had a pronounced short-term utilitarian aspect and many of its functions were, in any case, scarcely recognised. The greatest difficulty, however, has been the complexity of chemical reactions which the process of scale-up would have to take into account, as well as the physical factors present in any system.

Scale-up in chemical engineering may be carried out in a number of ways; by the multiplication of the number of units in parallel, by the adoption of equipment more suitable for large-scale operations than that used at a smaller scale, by the alteration of the basic flow-sheet, and by the use of models and the principles of similarity. This latter technique, which offers great possibilities to chemical engineering, has already been highly developed in other fields, although perhaps less complex. It has also been applied to problems of great breadth and variety, such as the influence of projected structures, i.e., bridges upon waterways and tidal waters; the design of dams, spill-ways, sluice gates, large turbines, centrifugal pumps, and so on, all of which have been successfully determined by means of models.

Osborne Reynolds pioneered their use for the design of life-boats and Froude used them for designing ships' hulls. However, in the application to chemical processes one encounters difficulties not met with in the other fields. Factors used by the chemist, such as reaction constants and space velocity, often have diffierent dimensions for different reactions, and the size of vessels so used often enters as an unseen factor. One of the primary requisites in this instance is a knowledge of all the factors that determine reaction rates and it is here that the chemical engineer is at a disadvantage compared with his confrères.

A reaction which proceeds satisfactorily on the laboratory scale may fail at the production level; conversely, a process which has been a failure on the small scale may yet become outstandingly successful on the factory scale, a notable example being the electrolytic process for aluminium. Despite the difficulties, many problems of this kind could be avoided by an appreciation of the method of dimensions. Had Hall been able to devise his small-scale experiments on the electrolytic preparation of aluminium with these principles as a guide, it is possible that he would have made a more reliable forecast of the performance of his prototype.

Two decades ago Damköhler attempted to overcome these disadvantages and proposed a number of rules defining similarity in chemical processes. His suggestion was that a number of dimensionless ratios should be maintained constant if dynamical chemical and thermodynamical similarity were to be maintained at both scales. But, from that time to the present, little seems to have been done in this important field, and for this reason the recent conference on scale-up is all the more valuable.

In the presentation of the data for flow of liquids and gases through pipes (one of the fruits of this technique), the relationship between two dimensionless quantities is given by a single function. This finding has been of great service to the practical man who wishes to determine his pipe sizes or pressure losses. In addition, it has reduced enormously experimental work in this sphere. Nevertheless, despite its universal use, this well-known finding has often been taken for granted without due recognition of the principles which produced it.

A striking example of what can be done with even limited scale-up rules is provided by the processing side of atomic energy production at Windscale. Here, the plant for recovering plutonium and uranium separately from fission products by a process of solvent extraction of dissolved irradiated fuel elements was developed direct from the laboratory scale without intervening pilot plant. Moreover, surprisingly little trouble was experienced in operation. There have been other applications of similitude to crushing and grinding in recent months by Andreasen, Rose* and others.

One of the problems of model theory in the field of chemical engineering is the need to produce less empirical forms of relationship between dimensionless groups. An interesting suggestion on this problem arising at the scale-up conference was the use of Bessel or other functions, instead of the usual empirical power functions. To this we would add a wider dissemination of actual model techniques along the lines of the paper devoted to furnace applications; a bringing together of the chemical kinetic and physical factors; and a greater understanding of the scope and limitations of the principles of similitude.

* Andreasen, A. H. M., and Rose, H. E. *Trans. Inst. Chem. Eng.*, 1957, **35**, 2 pp., 104, 98.

DESIGNING A PNEUMATIC CONVEYOR

Theoretical and practical aspects in the design of a pneumatic conveyor, from first principles, are briefly introduced. These are supported by a numerical example

by S. J. MICHELL, M.Sc., A.M.I. Chem. E. *

SYSTEMS for conveying bulk materials in air can be classified into two broad groups, namely: (1) low-pressure systems, in which the solid-air ratio and the velocities are fairly low, with the result that the pressure drop in the system is also low; and (2) high-pressure systems, characterised by large conveying rates and higher pressure losses.

To mark the distinction between the two systems, the maximum suction pressure that can economically be obtained with a centrifugal fan may be regarded as the limiting pressure. High-pressure systems will normally be operated by positive-pressure devices, such as turbo-blowers, with delivery pressures up to and over 30 psi, and turbo-compressors or positive-displacement compressors with delivery pressures as high as 120 psi. From the design point of view, there is no fundamental difference between the two systems, the choice being dictated by the duty required of the plant.

Design Factors

Conveying Velocities. The theoretical critical velocity for conveying a fine particle in air can be determined from Stokes' law. For particles larger than 100 microns, this terminal velocity may be calculated from Newton's law, or, when a rough estimation is sufficient, from the following useful formula[1]:

$$u = 250 \left(\frac{s}{s+1} \right) \sqrt{d}$$

in which u is the critical air velocity in ft/sec. required to lift the particle of d inches in diameter, when its specific gravity is s. In conveying, the particles must exceed many times the balancing velocity of the largest particle. In commercial practice the minimum air velocity is rarely less than 50 fps, and this increases greatly with the specific gravity of the particle conveyed. Since frictional losses, and hence the power requirement, are directly proportional to the square of the velocity (which for compressible fluids varies along the line), the choice of an optimum value constitutes a major problem. Although no rigid rules can be suggested, the following comparative figures[2] may serve as a rough guide in selecting the diameter of the conveying line. The existing conveying systems, handling coarse salt ($s = 1.24$), grain ($s = 0.7$) and ground cork ($s = 0.08$), are operated at air velocities of 160, 145 and 75 fps respectively, on a 30 tph basis.

Carrying Capacities. The carrying capacity of a pneumatic conveyor depends on the amount of air supplied and on the pressure difference between the two ends of the system. There is a large degree of flexibility in fixing the solid-air ratio for high-pressure conveyors. Once fixed, however, it will (along with the air velocity) determine the differential pressure required. In establishing the solid-air ratio a simple formula is used by the equipment manufacturers.[3] It relates the air rate (Q cu. ft/min.) to the rate of the material conveyed (T, short tons per hour) in the following manner:

$$Q = w \,.\, T \qquad \ldots\ldots (1)$$

where w is the density of the solid material, expressed in lb./cu. ft. For high-pressure systems the air rates are much lower, and their predetermination is largely a matter of experience.

Energy Losses. The principal data looked for when designing a pneumatic conveyor is the pressure difference—between the entrance of the conveyed material and its point of discharge—which must be maintained in order that the material can be continuously conveyed at the rate desired. A number of attempts have been made to establish the contribution of solid particles towards the total losses due to friction. The most recent investigation in this field seems to be that of Clark, *et al.*[4] Many earlier attempts can be traced in the work by Huggil,[5] which probably gives the most up-to-date information on this subject. In fact, no satisfactory correlations have yet been achieved.

In the following example the losses will be estimated from an empirical equation suggested for larger particles by Vogt.[6] The equation, derived originally by means of dimensional analysis, relates the many variables in the following way:

$$\alpha = A \,.\, \left(\frac{D}{d} \right)^z \left(\frac{\rho}{w} \cdot \frac{r}{Re} \right)^k + 1 \qquad \ldots\ldots (2)$$

where α is the ratio of the total loss to that due to the air

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alone at the same velocity. The latter can be estimated from Fanning's equation; D/d is the ratio of the pipe to the particle diameters; ρ/w the ratio of the air to the solid particle densities; r is the solid/air weight ratio; and Re is the Reynolds number. The constants A and k are determined from Reference 6, upon the evaluation of the dimensionless factor

$$\psi = \frac{\sqrt{\frac{1}{3}(w-\rho)\,\rho\,g\,d^3}}{\mu} \qquad \ldots . (3)$$

in which g is the gravity acceleration and μ the viscosity. The other symbols have the same meanings as for Equation (2). Any set of consistent units can be engaged in the equations.

Flow Equation. In an isothermal flow of a compressible fluid, the energy equation, when applied to the conveying system represented diagrammatically in Fig. 1, is given by

$$\int_2^1 V\,dp + \frac{\Delta u^2}{2g} + \Delta z = F \qquad \ldots . (4)$$

in which the symbols are as follows: V = specific volume, cu. ft/lb.; p = pressure, lb./sq. ft; u = linear velocity, ft/sec.; g = acceleration due to gravity (32.2 ft/sec.^{2}); $\triangle z$ = vertical distance between the two ends, ft; and F = energy losses between the two points selected, ft lb./lb. In such a selected system the work term disappears from the equation.

For moderate pressure differences, as normally encountered in conveying, the first term of the equation may conveniently be replaced by $V_{av}\,(p_1 - p_2)$, where V_{av} is the average specific volume. By substitution to Equation (4), it becomes:

$$V_{av}\,(p_1 - p_2) + \frac{\Delta u^2}{2g} + \Delta z = F \qquad \ldots . (5)$$

In two-phase (solid-gas) systems, Equation (5) can be written for each phase separately. Thus, for the gas phase only, taking

$$V_{av} = \frac{2RT}{M\,(p_1 + p_2)}$$

(where R = the gas constant, T = absolute temperature and M = the molecular weight of the gas), Equation (5) becomes:

$$\frac{2RT}{M}\,\frac{(p_1 - p_2)}{(p_1 + p_2)} + \frac{\Delta u^2}{2g} + \Delta z = F \qquad \ldots . (6)$$

In writing a similar equation for r pounds of the solid material, being carried through by one pound of the gas, the following assumptions are made:

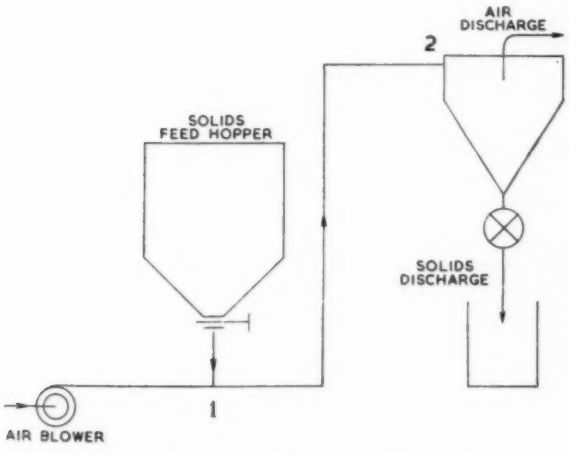

Fig. 1 Pneumatic conveying system, the basic design of which is given in the text.

(a) the gas and the solid particles flow at the same velocity (although experience shows that there is a considerable slip between the solid and gas particles); and

(b) the average specific volume of the solid material is negligibly small. Equation (5) then reduces to the following form:

$$r\,.\,\frac{\Delta u^2}{2g} + r\,\Delta z = r\,F_s \qquad \ldots . (7)$$

where F_s is the energy loss due to the solid particles only.

The addition of Equations (4) and (5) results in

$$\frac{2RT(p_1 - p_2)}{M(p_1 + p_2)} + (1 + r)\,.\,\frac{\Delta u^2}{2g} + (1 + r)\,\Delta z = F + r\,F_s \ldots . (8)$$

Further modification of the latter is made by replacing the velocities with mass rates.

Since $u = GV = G\,.\,\frac{RT}{MP}$

(where G is the mass rate expressed in lb./ft^2 × sec.)

$$\Delta u^2 = u_1^2 - u_2^2 = \left(\frac{GRT}{M}\right)^2 \left(\frac{1}{p_1^2} - \frac{1}{p_2^2}\right)$$

Also by definition,

$$\alpha = \frac{F + rF_s}{F}$$

By substitution, Equation (8) becomes:

$$\frac{2RT}{M}\left(\frac{p_1 - p_2}{p_1 + p_2}\right) + \frac{(1 + r)}{2g}\left[\frac{GRT}{M}\right]^2 \left(\frac{1}{p_1^2} - \frac{1}{p_2^2}\right) + (1 + r)\,(z_1 - z_2) = \alpha\,F \qquad \ldots . (9)$$

For a given system some terms of the equation may be taken as constants.

Let $C_1 = \frac{2RT}{M}$, and

$$C_2 = \frac{(1 + r)}{2g} \times \left(\frac{GRT}{M}\right)^2$$

to obtain the final form

$$C_1\left[\frac{p_1 - p_2}{p_1 + p_2}\right] + C_2\left(\frac{1}{p_1^2} - \frac{1}{p_2^2}\right) + (1 + r)\,(z_1 - z_2) = \alpha F \qquad \ldots . (10)$$

Numerical Example

A granular material (specific gravity, s, = 1.05; particle diameter d, = 0.12 in.) is to be conveyed continuously at the rate of 40 tons an hour, using air as the carrier gas. The vertical distance between the two ends of the system will be 80 ft, and the estimated length of the piping will not exceed 100 ft. Required is the specification of the plant equipment.

Solution. Referring to Fig. 1, the discharge end is open to a cyclone receiver operated at atmospheric pressure, so that p_2 = 14.7 psia.

Blower Capacity. From Equation (1), the optimum air rate would be:

$$Q = w\,.\,T = (1.05)\,(62.4)\,(40)\left(\frac{2240}{2000}\right) = 2980 \text{ cu. ft/min.}$$

For a high-pressure system a much lower figure should be assumed. The lower limit in this instance is fixed by the minimum capacity of the commercial turbo-blowers, which is 2000 cu. ft/min., assumed at 70°F and normal barometric pressure. On a weight basis, the air rate supplied by the blower will then be:

$$G_t = \frac{2000}{359} \times \frac{492}{530} \times \frac{29}{60} = 2.5 \text{ lb./sec.}$$

Pipe Diameter. The diameter of the line will now be fixed at D = 6 in., corresponding to 170 fps approximately

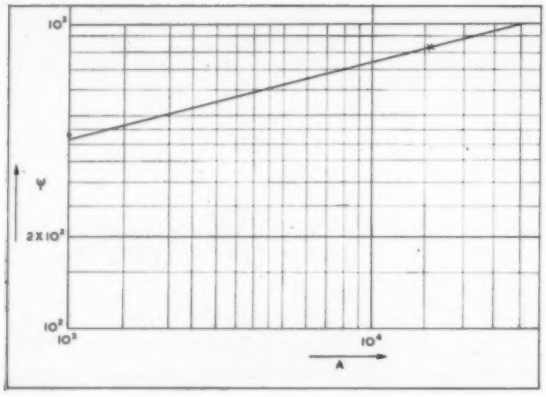

Fig. 2. Plot of A v. ψ. *Reproduced for the narrow range required for the numerical example from Reference* 6.

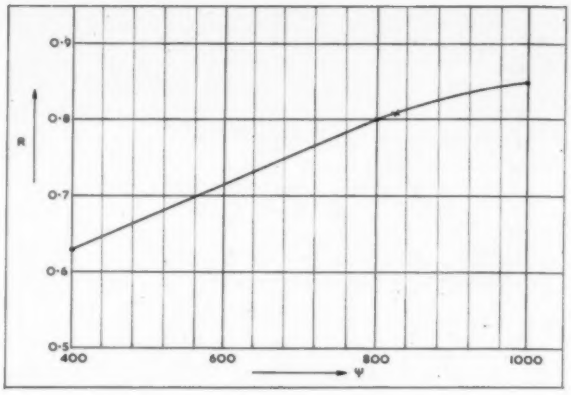

Fig. 3. Plot of ψ v. k. *Reproduced from Reference* 6 *for the range required for the numerical example.*

when based on the highest velocity at the upper end of the line. This is in fair agreement with present commercial practice as previously outlined.

Pressure Drop. The entrance pressure (p_1) will be calculated from Equation (10). The components of the equation will be evaluated in terms of the unknown pressure as follows:

$$V_{av} = \frac{1}{\rho} = \frac{2RT}{M\,(p_1 + p_2)} = \frac{(2)\,(1540)\,(530)}{(29)\,(p_1 + 14.7 \times 144)}$$

$$\therefore V_{av} = \frac{56{,}200}{(p_1 + 2117)}$$

$$G = \frac{G_t}{D^2\frac{\pi}{4}} = \frac{2.5}{(0.5)^2\frac{\pi}{4}}$$

$$\therefore G = 12.72 \text{ lb/(ft}^2\text{)(sec.)}.$$

Absolute viscosity of air at 70°F is 0.017 cps.

$$Re = \frac{DG}{\mu} = \frac{(0.5)\,(12.72)}{(0.017)\,(0.000672)}$$

$$\therefore Re = 5.58 \times 10^5$$

Fanning friction factor $f = 0.004$.

$$F = \frac{4f\,G^2\,V_{av}^2\,L}{2\,g\,D} = \frac{(4)\,(0.004)\,[12.72 \times 56{,}200]^2 \times 100}{(64.4)\,(0.5)\,(p_1 + 2117)^2}$$

$$\therefore F = \frac{2.54 \times 10^{10}}{(p_1 + 2117)^2}$$

From Equation (3)

$$\psi = \frac{\sqrt{\frac{1}{3}\,(w - \rho)\,g\,d^3\,\rho}}{\mu}$$

$$= \frac{\sqrt{\frac{1}{3}\,(1.05)\,(62.4)\,(32.2)\left(\frac{0.12}{12}\right)^3 \times \frac{1}{56{,}200} \times \sqrt{p_1 + 2117}}}{(0.017)\,(0.000672)}$$

$$\therefore \psi = 9.83\sqrt{p_1 + 2117}$$

Solid-air weight ratio.

$$r = \frac{(40)\,(2243)}{3630} \times \frac{1}{2.5} = 9.95.$$

From Equation (2),

$$\alpha = A\left(\frac{D}{d}\right)^2\left[\frac{\rho}{w}\cdot\frac{r}{Re}\right]^k + 1$$

$$= A\left(\frac{6}{0.12}\right)^2\left[\frac{p_1 + 2117}{(56{,}200)\,(65.5)} \times \frac{9.95}{5.58 \times 10^5}\right]^k + 1$$

$$\therefore \alpha = 2500\,A\,[4.84 \times 10^{-12} \times (p_1 + 2117)]^k + 1$$

$$C_1 = \frac{2\,RT}{M} = \frac{(2)\,(1540)\,(530)}{29}$$

$$\therefore C_1 = 5.62 \times 10^4$$

$$C_2 = \frac{(1 + r)}{2\,g}\left(\frac{G\,R\,T}{M}\right)^2 = \frac{(1 + 9.95)}{64.4}\left[\frac{(12.72)\,(1540)\,(530)}{29}\right]^2$$

$$\therefore C_2 = 2.18 \times 10^{10}$$

$$(z_1 - z_2)\,(1 + r) = (-80)\,(1 + 9.95) = -875.$$

Substitution to Equation (10) and rearrangement leads to

$$(5.62)\,(10^4)\left(\frac{p_1 - 2117}{p_1 + 2117}\right) - 2.18 \times 10^{10}\left(\frac{1}{2117^2} - \frac{1}{p_1^2}\right) - 875 = \alpha F.$$

Solution by graphical method gives the required pressure, $p_1 = 5040$ psf $\equiv 35$ psia.

As a check on the foregoing,

$$F = \frac{2.54 \times 10^{10}}{(5040 + 2117)} = 498$$

$$\psi = 9.83\sqrt{7157} = 832.$$

From Reference 6,* for $\psi = 832$, $A = 15{,}500$, $k = 0.81$,

$$\alpha = 2500\,A\,[4.84 \times 10^{-12}\,(p_1 + 2117)]^k + 1$$

$$\alpha = 36.2$$

Comparing both sides of Equation (10):

$$5.62 \times 10^4\left(\frac{5040 - 2117}{5040 + 2117}\right) - 2.18 \times 10^{10}\left(\frac{1}{2117^2} - \frac{1}{5040^2}\right) - 875 = 36.2 \times 498$$

$$22{,}900 - 3{,}980 - 875 = 18{,}030.$$

The left-hand side equals 18,045 and the right-hand side equals 18,030, which is satisfactory. The power specification is left to the manufacturer. We therefore arrive at the following equipment specification: A turbo-blower of 2000 cu. ft/min. capacity, and with a delivery pressure of not less than 35 psia is required. The conveying line is to be made of 6-in. diameter pipe, the total length of which should not exceed 100 ft.

* In Reference 6, different readings are obtained for non-vertical sections of the line. However, one is on the safe side when disregarding this difference.

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METHODS FOR PRODUCING UNIFORM GAS FLOW IN PROCESSING EQUIPMENT

This article offers practical design data for various means of promoting uniform flow in industrial processing equipment

THE feed connection of many vessels, such as catalytic reactors, adsorbers, electrostatic precipitators, absorption columns, cyclonic separators, etc., are often of very much smaller diameter or cross-sectional area than the vessels themselves. In such cases, unless suitable measures are adopted, the distribution of fluid flow at various parts of a vessel will be uneven, so that the full design performance of a given vessel will not be realised.

Two methods of achieving uniform flow are available, and are based upon experimental work by Idel'chik.[1,2] These are as follows: (1) an additional resistance to fluid flow may be included in the design; and (2) flow-guiding devices may be installed whose resistance is virtually negligible. The former method makes use of flat gratings, perforated sheets or shallow beds of packing or any other mechanical device which distributes a resistance to the main flow of fluid. In the second method, the apparatus used may take the form of guide blades, which may be of aerofoil section, baffles or plates. These are fixed in the equipment at points where there is a change in the direction of flow. It is also possible to use a combination of both of these main methods, i.e., grids and guide plates may be used together. The various practical methods are discussed in greater detail below.

Single Grids for Perforated Plates

The term "grid" is used to denote any type of resistance distributed over the cross-section of the vessel as compared with a concentric orifice. It is found with such devices that smoothing effect is not constant, but increases with the resistance of the device employed. It is useless to select grids or perforated plates for gas distribution without taking into account their resistance and their geometry. When a fluid flows into a vessel through an inlet of smaller cross-section than that of the vessel itself then the greater the ratio of cross-section of the vessel to that of the inlet, the greater must be the resistance of the flow-smoothing element. The relation between the resistance of a grid for uniform distribution of fluid velocities and the ratio of the vessel and inlet cross-section is given by the following empirical expressions:

$$\text{For } \frac{A_v}{A_f} \leqslant \frac{6.5}{\sqrt{N_o}}$$

$$f_{opt} = N_o \left(\frac{A_v}{A_f}\right)^2 - 1 \quad \ldots . (1)$$

$$\text{and for } \frac{A_v}{A_f} \geqslant \frac{6.5}{\sqrt{N_o}}$$

$$f_{opt} = 1.5 \left[N_o \left(\frac{A_v}{A_f}\right)^2 - 1\right] \ldots . (1a)$$

In both cases the loss coefficient, $f_{opt}, = \dfrac{\Delta P}{\dfrac{\rho V^2}{2g}}$.

The symbols have the following meanings:

A_1 = cross-sectional area of feed connection at a distance from the vessel, m^2;
A_f = cross-sectional area of feed connection adjacent to vessel, m^2;
A_v = cross-sectional area of vessel normal to direction of flow, m^2;
P = pressure loss, kg/m^2;
g = acceleration of gravity, m/sec.^{2};
ρ = fluid density, kg/m^3;
V = fluid velocity, m/sec.; and
f_{opt} = loss coefficient
N_o = coefficient characteristic of inlet velocity

A perforated plate or grid must be used with caution, because at some distance downstream of the grid there is a pronounced tendency for the velocity profile to become irregular (Fig. 2). This increases with the area ratio $\left(\frac{A_v}{A_f}\right)$ beyond certain limits, determined by the following formulæ:

$$\frac{A_v}{A_f} \simeq \frac{3.0}{\sqrt{N_o}}$$

$$\frac{A_v}{A_f} \simeq \frac{6.5}{\sqrt{N_o}} \quad \ldots . (3)$$

With the packed-bed type of flow distributor no such limitation exists. For a flat perforated plate of thickness t, such that $\frac{t}{d_o} \leqslant 0.5$, the loss coefficient, f_p, may be estimated from

$$f_p = (0.707\sqrt{1 - R_a} + 1 - R_a)^2 \cdot \frac{1}{R_a^2} \quad \ldots . (4)$$

where R_a = ratio of grid (or plate) free area, A_f, to its projected area, A_p. Values of f_p for different values of R_a are given in Table II, Fig. 3.

In Equation (4), in order to find the value of A_f from which the details of the grid can be determined, f_p is first determined from Equation (1) or (1a).

Where the vessel has a central inlet, the minimum distance at which the grid should be placed from the point of entry of the fluid into the vessel should be 0.6 D_o (inlet diameter or side). For a side entry to the vessel, the minimum distance should be 1.4 D_o from the axis of the inlet.

Sometimes the amount of spread produced by a flow-smoothing grid has to be checked, in which case the expression

$$\frac{A_j}{A_v} = \frac{A_f}{A_v}\sqrt{\frac{1 + 0.67 f_p}{N_o}} \quad \ldots . (5)$$

is employed, where

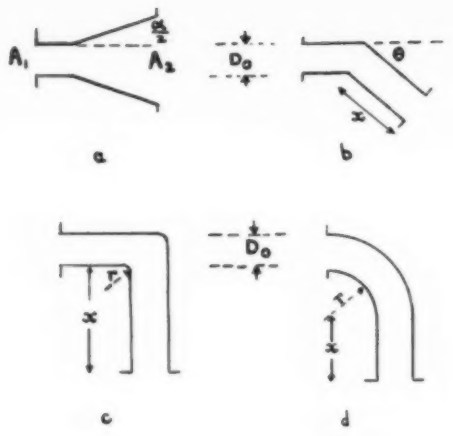

Fig. 1—TABLE I. Values of N_o for Various Types of Inlet Connection at Different Velocities

(a) Diffuser	$\frac{A_f}{A_1} >$	5.			
α	16	20	30	60	> 60
N_o	4	5	6	10	$\approx \left(\frac{A_f}{A_1}\right)^2$
(b) Sharp 45-degree bend.					
x/D_o	0-1.0	3.0	>5		
N_o	1.35	1.25	1.05		
(c) Sharp 90-degree bend.					
x/D_o	1.2	3.0	6.0	>10	
N_o	3.5	2.8	1.3	1.05	
(d) Swept 90-degree bend.					
x/D_o	0-0.5...	1.0	2.0	3.0	>4
N_o	1.8	1.4	1.2	1.1	1.05

A_f = area of spread of jet, m²
f_p = loss coefficient for flow-smoothener obtained from Equation (1), (1a) or (4).

Systems of Flat Grids

Flat grids are more successful as gas-distributing devices when several are used in series instead of singly (Fig. 4). The number of grids, N_g, required for a given case can be determined by means of the following expressions:

$$N_g \geq 0.33 \frac{A_v}{A_f} \sqrt{N_o} \qquad \ldots . (6)$$

which refers to side entries, whereas for central feed connections

$$N_g \geq 0.16 \frac{A_v}{A_f} \sqrt{N_o} \qquad \ldots . (7)$$

If several grids are used in series, their free areas should be identical, in which case their loss coefficients can be determined by

$$f_p = N_o \left(\frac{A_v}{A_f}\right)^{2/N_g} - 1 \qquad \ldots . (8)$$

The amount of spread of flow brought about by each grid can be estimated from the relation

$$\frac{A_{ng}}{A_v} = \frac{A_v}{A_f} \left(\frac{\sqrt{1+f_p}}{N_o}\right)^n \qquad \ldots . (9)$$

where A_{ng} represents the area of spread at the nth plate or grid. The optimum spacing for grids in series lies between 0.15 to 0.20 D_1, where D_1 is the characteristic dimension of the vessel's cross-section (diameter or largest side).

It should not be concluded from the foregoing that an increase in resistance in a system will lead automatically to uniform flow within the system. For example, a single inlet without additional means can provide uniform conditions although, generally, a construction which permits such an achievement will seldom be an economic one.

A single jet will spread out gradually until its flow pattern is practically uniform. The jet fluid in the process of spreading mixes with the stagnant or slowly moving fluid surrounding it. By transfer of momentum, the latter is accelerated in the direction of flow and, as mixing proceeds, so the central high-speed core diminishes and finally disappears. At this point the flow will be substantially uniform, but the process requires space for its completion. If an obstacle or obstacles are placed in the path of the jet and not coaxially with the core or orifice, then the jet may be caused to spread out rapidly. However, as we have seen from Fig. 2, a distortion of flow occurs at some distance downstream of a resistance, so that the purpose of installing such a device is defeated.

For this reason, a perforated plate or other smoothing device should not be situated too far from the face area at which uniformity of flow is required. For example, it would be a mistake to fit a grid at a considerable distance from the elements of an electro-precipitator. The best results would be obtained by placing it close to the elements.

There are other pitfalls which the designer must avoid when using smoothing devices, especially in cases where the smoothing process is followed by a further one wherein solid matter is being separated from the fluid. For example, with a multi-cyclone type of dust separator, the smoothing device might give rise to centrifugal effects—due to sharp changes in direction of flow—capable of producing a higher-than-average concentration of dust around a very small proportion of the total number of cyclone elements.[5]

Using Guide Baffles or Vanes

If the inlet to a vessel is at some angle to the direction of flow in the vessel and its cross-section is equal to that of the vessel, an effective method of flow equalisation can be obtained by the use of guide vanes as shown in Figs. 6 and 7. This method will not lead to any local concentrations of suspended material in the main fluid stream.

The procedure for designing a blade assembly is as follows. Each blade is made of sheet metal with a cylindrical surface whose length is equal to one-quarter of the circumference of the cylinder. The optimum or minimum number of blades is then calculated from the following simple formulæ:

$$n_{opt} = 1.4 \frac{S}{t} \cong 1.4 \frac{S}{kD_o} \qquad \ldots . (10)$$

$$n_{min} = 0.9 \frac{S}{t} \cong 0.9 \frac{S}{kD_1} \qquad \ldots . (11)$$

where $S = \sqrt{D_o^2 + D_1^2}$ = distance between the tips of internal and external angles of bend of gas flow at point of turn in gas flow, m; D_o = side or diameter of inlet connection to vessel in the plane of change of direction of flow; D_k = side or diameter at cross-section of vessel; $t = kD_o$, chord of blade; and k = a coefficient varying from 0.25 to 0.5 according to the dimensions of the vanes. When the chord of the blade is large k is also large, but the number of blades decreases as k increases and vice versa.

A construction with a number of blades determined from Equation (10) will have a more uniform velocity profile than one obtained by means of Equation (11). In some cases, however, it is enough to use the smaller number of blades, especially in the following cases in which additional smoothing devices are provided.

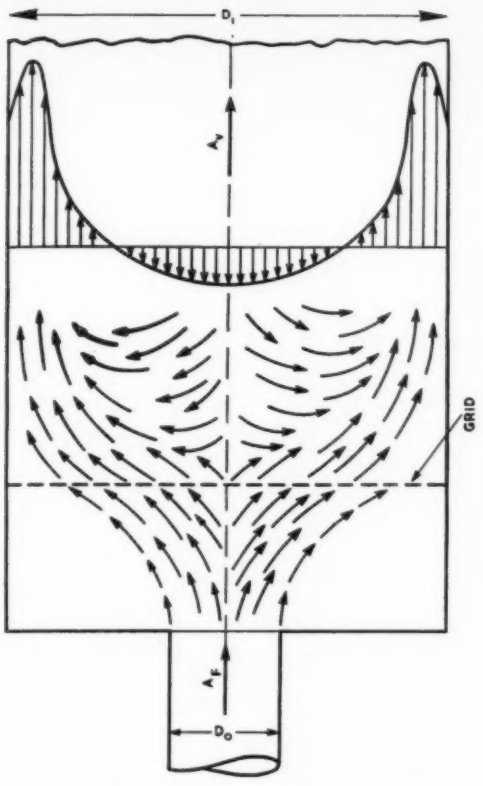

Fig. 2. Diagram illustrating distortion of flow downstream of grid.

The arrangement of blades at the plane where the flow changes direction is such that their distance apart is given by the following expressions:

$$\text{For optimum number of blades, } d_1 = 0.67\frac{S}{n_0+1}\left(1+\frac{i-1}{n_0}\right) \quad \ldots . (12)$$

$$\text{For minimum number of blades, } d_1 = \frac{S}{n_m+1}\left(0.5+\frac{i-1}{n_m}\right) \quad \ldots . (13)$$

where i is the number of the spacing between two adjacent blades starting with the space between the blade and the wall as 1.

For an ordinary bend or elbow with a small $D_1:D_0$ ratio, say of the order of 0.7 to 1.5, the fitting of blades in the bend presents little difficulty. In this case the distance of the first vane from the side of the trunking is based upon the inner surface of the blade, whereas the distance between succeeding blades is based upon their outer surfaces. In the case of a sharp elbow, the extreme distances are measured from the inner and outer angles of the bend respectively. The extreme spacings are readily calculated from the following formulæ:

$$d'_i = d_1 - z$$
$$d'_{n+1} = d_{n+1} + z,$$

where z is the camber of a vane (see Fig. 5).

In the case where the ratio $D_1:D_0$ of a right-angle inlet to a vessel is very large, then the procedure for the design of the blades system may be as shown in Fig. 6.

The angle of incidence, α, may be obtained from Table III for different $D_1:D_0$ ratios.

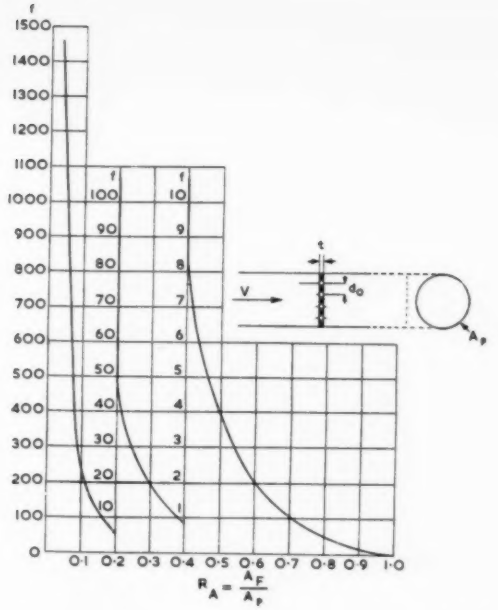

Fig. 3—TABLE II. Loss Coefficient for Grids where $\frac{t}{d_0} \leqslant 0.5$

R_a	0.02	0.03	0.04	0.05	0.06	0.08	0.10	0.12	0.14
f_p	7050	3100	1440	1075	732	398	247	165	117
R_a	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32
f_p	86	66	52	41	32	27	22	18	16
R_a	0.34	0.36	0.38	0.40	0.43	0.47	0.50	0.52	0.55
f_p	13	11.5	9.6	8.3	6.6	4.9	4.0	3.5	2.8
R_a	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.0
f_p	2.0	1.4	0.97	0.65	0.42	0.25	0.13	0.05	0.0

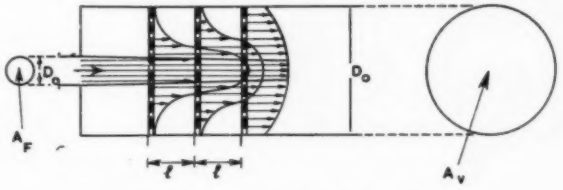

Fig. 4. A system of grids in series.

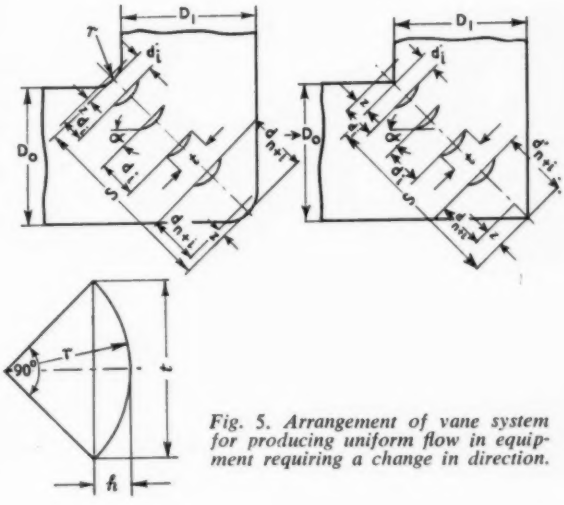

Fig. 5. Arrangement of vane system for producing uniform flow in equipment requiring a change in direction.

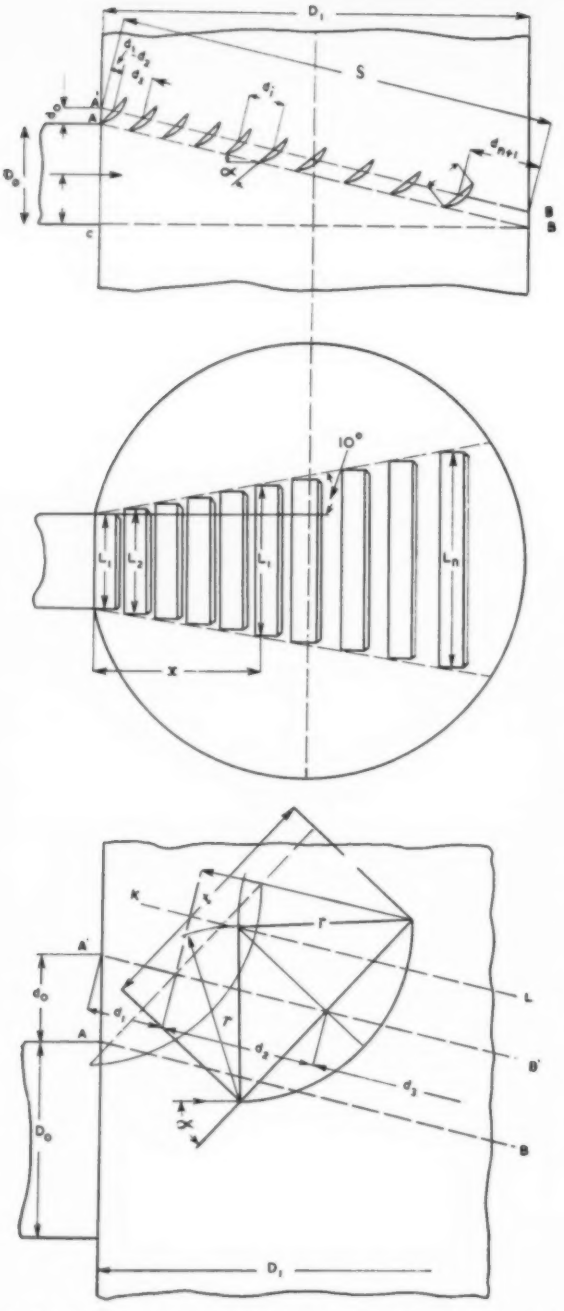

Fig. 6. Guide vane arrangement for vessels with relatively small inlets. The method of laying out the vanes is as follows: (1) *The line A-B is drawn by joining the points formed by the intersections of the upper edge of the supply duct with the internal wall of the main vessel and the internal section of the vessel's outer wall with the lower edge of the feed connection.* (2) *A line A'-B' is drawn parallel to the line A-B at a vertical distance equal to* $\frac{t}{3}$ *sin* α *from it. This line is the join of the centres of the blades.* (3) *The distances between chords of the blades are marked out along the line A'-B'.* (4) *Through the ends of the various divisions,* d_1, d_2, d_3, *etc., made in the line A-B, chordal lines are drawn at an angle* α *to the direction of flow of the entering fluid.* (5) *The chord length is marked out on each of these lines with the chord centres on A'-B'.* (6) *Arcs are described from the ends of the chords of radius equal to the blade curvature. The points of intersection will be the centre points of the blade curved surfaces; their join, line K-L, is then the centre line of the blades.* (7) *Arcs are now described from the above centres and of radius equal to the blade curvature to intersect the chords. These arcs will then represent the blades proper.*

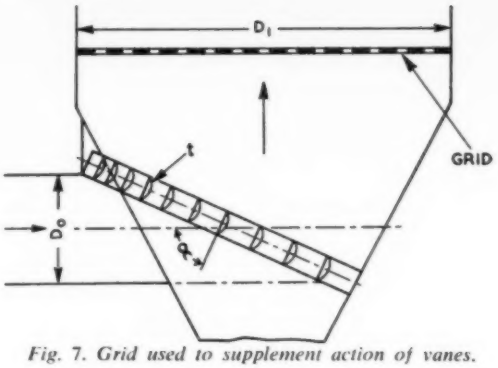

Fig. 7. Grid used to supplement action of vanes.

TABLE III

$D_1 : D_0$	$\alpha°$	$D_1 : D_0$	$\alpha°$
1.0	48±2	5.0	57±3
1.3	51±2	10	60±3
2.0	53±2	20	70±3

A less effective method is the use of flat instead of curved plates. With these, the best angle of incidence is about 85 degrees. Spacing of flat plates is determined in the same way as for curved plates. Where the inlet connection is much smaller than the vessel diameter, for example when the ratio $D_1 : D_0$ is greater than 10-20, it is often necessary to use a combination of devices to get uniform distribution of flow.

Combined Vane and Grid Systems

Such systems are worth installing when the designer not only aims at a uniform velocity profile but also when he wishes to avoid swirling effects. The latter effects are sometimes generated downstream of a vane arrangement, especially where large ratios of $D_1 : D_0$ exist.

When a vessel has a small inlet, the entering fluid leaves the connection in the form of a small jet and, generally, it will spread out in the form of a cone with an apex angle of about 20 degrees. This fact may be taken into account when designing flow-smoothing systems using vanes. The usual method is to give the blade a variable length, starting with the smallest size near the feed inlet and increasing it the further one proceeds from it. The dimensions of any particular blade are given by:

$$L = D_0 + 2\,x \tan 10°$$
$$= D_0 + 0.35\,x.$$

x = distance from feed inlet (see Fig. 7).

If a grid is chosen to supplement a vane system, then its dimensions may be obtained from the formulæ already given. In Equation (1), however, the product of D_0 and D_1 is substituted for A_f. Similarly, the value of N_0 in Equations (1) and (1a) is 1.5 for cambered guide plates and approximately 2.0 for flat plates.

Grid Fitted at Chamber Inlet

From a practical point of view, the combination formed by an expanding inlet, grid and guide-blade system, as shown in Fig. 10, is both effective and simple. Here the inlet opening is made equal in diameter to that of the working chamber. The feed inlet expands to its maximum cross-section quite sharply and within a distance equal to the diameter of the unexpanded portion D_c.

In order to secure uniform velocity distribution throughout the whole cross-section of the inlet opening, the distributing plate or grid has to be situated at a distance (d_g) not less than 0.6 D_3 from the plane at the inlet transverse to the main flow.

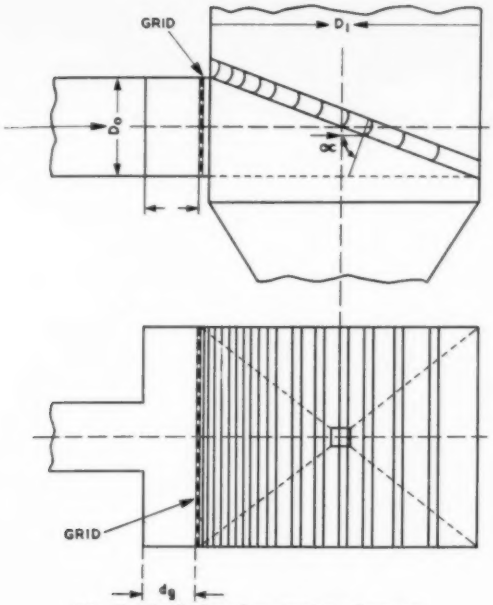

Fig. 8. Grid placed upstream of vanes.

To determine the dimensions of a grid using the equations previously given, A_v is taken to be the area of the inlet opening to the chamber and A_f the area of the narrow part of the feed inlet.

For uniform velocity distribution over the whole cross-section of the main vessel, guide vanes, curved or flat, can be fixed at a position in the vessel where the flow changes direction, using the methods already described.

Smoothing Flow by Means of Dividing Walls

In some apparatus the supply of fluid is made through a smoothly-expanding connection (diffuser). In such cases, when the use of long narrow-angled conical-diffusers is precluded, short wide-angled diffusers, provided with internal dividing walls, may be used as shown in the example given in Fig. 9 which is designed for a cone angle of 60 degrees. At present there is little design data for such guide walls, and the recommendations of Table IV must be regarded as approximations only.

TABLE IV. Number of Guide Walls and their Angles of Inclination for Diffusers of Different Angles

Included angle of diffuser, a°	Number of dividing walls, n_w	Overall angles of walls a°_1	a°_2	a°_3	a°_4
45	4	13	9	7	0
60	4	20	13	7	0
90	6	23	16.5	10	7

A method for the design of dividing walls is given in Fig. 9. Dividing walls by themselves will not produce a completely uniform flow of fluid throughout a vessel; indeed, they give only a partial smoothing effect. If a more uniform condition is required, then, in addition, a grid must be placed downstream of the diffuser and its guide walls.

At present there is some difficulty in designing supplementary grids because of the uncertainty of the effect of guide walls. However, a good general rule is to assume that the dividing walls cause a threefold spread of flow, so that in Equation (1) or (1a) the appropriate value of A_f should be three times the cross-sectional area of the narrow part of the inlet.

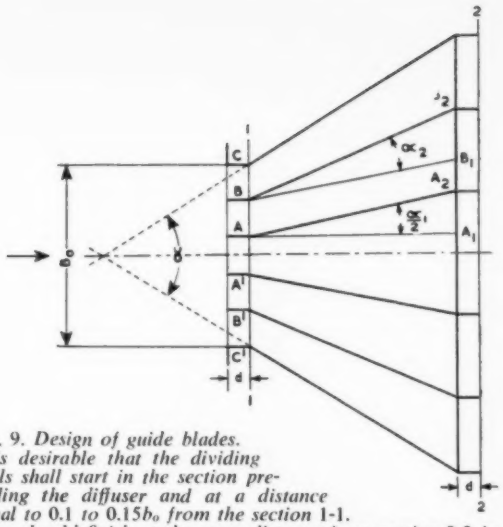

Fig. 9. Design of guide blades. It is desirable that the dividing walls shall start in the section preceding the diffuser and at a distance equal to 0.1 to 0.15b_0 from the section 1-1. They should finish at the same distance from section 2-2 in the straight part of the outlet. These straight sections of the dividing walls are made parallel to the axis of the diffuser. (1) The width of the inlet section of a diffuser is divided into n_1+1 equal sections AB, A'B', and so on. (2) the line A-A_1 is drawn parallel to the axis of the diffuser. (3) The line A-A_2 is drawn at an angle $\alpha_1/2$ to the line A-A. The first line gives the position of the dividing wall. (4) Another line B-B_1 is drawn parallel to the first dividing wall. (5) The line B-B_2 is then drawn at an angle α_2 to the line B-B_1. The former line gives the position of the second dividing wall. The positions of the remaining walls are fixed in the same way.

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Gas Production in Great Britain

THE AMOUNT OF gas made available in Britain during the nine months ended December, 1956, increased by 1.5% to 2044 million therms, according to statistics recently issued by the Gas Council. The quantity of surplus gas purchased from coke ovens and oil refineries increased by 12.8% to 340.5 million therms. However, the amount of coal-gas made increased by only 0.3% to 1474.2 million therms and the make of water-gas decreased by 6.7% to 204.7 million therms, so that the total production of coal- and water-gas was down by 0.5%. During the nine months, 19,611 thousand tons of coal were carbonised for gas making, an increase of 0.4%. For the production of water-gas 770.2 thousand tons of coke (−5.4%) and 66.5 million gallons of gas and heavy oil (a decrease of almost 10%) were used. The by-products of the industry all showed an increase—the amount of coke was 8989 thousand tons (+0.4%), of crude tar 1418 thousand tons (+1.3%), and of crude benzole 21.8 million gallons (+4.8%). The new plant brought into use during the period of the report had a daily capacity of 77 million cu. ft of gas, an increase of 20% over the figure for the corresponding part of the previous year. Of this equipment, carbonising plant was responsible for 40.1 million cu. ft, and showed an increase of 44.2% over the previous figure. 1602 miles of mains were laid—350 miles fewer than in the previous period. Industrial consumption of gas rose by 2.1% to 541.8 million therms, but domestic consumption fell by 0.4% to 964.7 million therms. The average revenue per therm of gas sold increased by 9.3% to 18.98d. At the end of January, 1957, the gas industry employed 139,941 persons, of whom 103,126 were operatives. The total was 1.6% less than a year previously.

NUCLEAR HEAT FOR THE DESALTING OF BRACKISH OR SALT WATER

Processes using large quantities of heat as the energy source for water purification are the subject of this article. The heat from an atomic reactor is one such source considered

by J. LEICESTER, M.I.Chem.E., A.I.Mar.E.*

FRESH water supply is a factor of major importance in the life of the community, and in many cases may be the deciding factor as to whether industrial or agricultural development of an area can take place. With rising living standards and increased industrialisation, it is becoming ever more difficult to find enough fresh water to meet demand. In the U.S.A. and throughout Europe the problem is being actively tackled, while in the British Commonwealth it is also being realised how development schemes may be delayed due to the fact that the only water available is brackish or salt water. The solution of these problems is an international task, and experimental and development projects are in progress in several countries which are directed towards one ultimate goal, the provision of fresh water in quantity and at an economic cost, wherever it may be required.

In this article it is intended to consider only those processes that use large quantities of heat as the energy source for water purification, namely distillation and solvent extraction techniques, and to examine the possibility of the use of heat supplied from some form of atomic reactor. In this respect, the problem can only be examined on the premise of information provided by the experts at Harwell and endeavour, assuming certain basic information, to translate this into probable costs for the large-scale desalting of water.

A typical figure for water usage per person a day is of the order of 1500 gallons, inclusive of agriculture, industry and domestic requirements. For a community of only 50,000 people, this would require a water supply of some 75 million gallons a day. The current cost of this water for all purposes amounts to an average figure of 0.8d. per 1000 gallons for irrigation, 2s. 8d. per 1000 gallons for domestic needs, and 2s. 3d. per 1000 gallons for industrial usage. These figures are only a very rough guide as to the cost level that may have to be taken into account when desalting brackish or salt water supplies. It will readily be appreciated that the figures apply to an area where the normal services of civilisation are in existence. For undeveloped areas, where there may be valuable potential development envisaged if fresh water were available, then the costs might easily be multiplied by a factor of 10, and still prove of sufficient interest to warrant consideration of methods of water purification. In certain of our colonial territories, costs of from 40s. up to as high as 400s. per 1000 gallons are being charged for supplies of fresh water.

From an earlier article,[1] it will be noted that it has been already forecast that for large-scale production units of the order of 1 million gallons a day output the lowest cost for vapour recompression methods is of the order of 7 to 7.5s. for 1000 gallons according to the desalting range. For multi-stage flash evaporators, the cost is not expected to drop below 16s. per 1000 gallons and for solvent extraction methods a forecast of 10s. per 1000 gallons is given.

Evaporation Techniques

When considering processes involving the purification of water by evaporation and recondensation of the vapour, it is obvious that the operating locality can greatly influence the type of plant and ultimate cost of water produced. For instance, if a development scheme is considered which envisages the use of steam and cooling water as part of a major process plant, then obviously it would be prudent to use any available process or pass-out steam in some form of multi-effect or flash-type evaporator plant. If, however, a situation arose where steam and cooling water were not available either at all or in sufficient quantity to support a development scheme, then consideration would have to be given to the self-contained, diesel-driven vapour-compression evaporator which requires no external source of heat or cooling water. Again, one must consider other methods of evaporation dependent upon the climatic and geographical conditions of the development area. Is the amount of sunshine a year sufficient to make solar evaporation an attractive method, or are there other geographical features available that would allow evaporation processes to be developed based upon thermal differences, either in the sea or inland lakes? All these factors must be assessed before it is possible to decide which particular process might best suit a development area.

In the light of present developments in the field of atomic energy, it is essential that we should also consider this source of heat to see whether it might become economic

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for use in connection with the distillation of salt or brackish water. It is conceivable that future atomic power plants will be built as part of the major colonisation and industrial development of areas that are at the moment sparsely populated or completely unpopulated. In this case, it is probable that low-grade heat would be available in large quantities. In addition, we must also consider the possible use of an atomic reactor as a direct source of heat for distillation. It is this application which offers the most intriguing possibilities for the future arid areas of the world.

If we are to consider the possibility of a nuclear reactor as the primary source of heat for an evaporation process, then it would appear logical to consider a system such as that shown in Fig. 1. Here, a nuclear-reactor boiler is assumed in which the primary steam is produced at about 150 psig. This steam (possibly slightly radioactive) is then passed to a secondary boiler or heat exchanger producing steam at about 50 psig. The non-radioactive steam produced from this secondary boiler would then be used in a more or less conventional design of evaporator. The other future possibility would be the design of a nuclear heating system that would directly heat the evaporating liquor in place of the less-efficient indirect-heating method. For safety and health reasons, this may be a more difficult design to envisage, and this assessment is based upon the indirect system of heating using a secondary heat exchanger.

The possible costs of steam produced by a nuclear boiler will obviously depend largely upon the capital costs involved, the steam output of the unit and also the pressure at which it is required to operate.[2]

In considering this application to large-scale fresh-water production, it is clear that it can only be of interest for very large capacity plants such as might be envisaged for the centralised purification and supply of water to a whole community. The following estimates, therefore, are based on a plant capable of supplying a minimum of 10 million gallons a day and up to a maximum of 100 million gallons a day. For the production of 10 million gallons a day and assuming the use of a 10-effect flash-type evaporator, this would require the supply of some 20 million pounds of steam a day or approximately 1 million pounds of steam an hour. This figure would rise to the upper limit of 200 million pounds a day or about 10 million pounds of steam an hour.

If it is assumed that 1000 pounds of steam is equivalent to approximately 1 million Btu and taking an average of the various cost figures calculated for steam produced from an atomic boiler, then it would seem that a cost of around 5s. per 1000 pounds can be achieved. This figure is based upon a 40-megawatt (in terms of steam heat) installation, and if larger units were feasible then, undoubtedly, the cost per 1000 pounds of steam would be reduced accordingly.

For the two parameters of water production, a reactor boiler capable of producing approximately 300 megawatts of heat would be required, or, for the larger unit, 3000 megawatts of heat an hour. From a recent paper by Nicholls,[3] in which was discussed the effect of size of reactor on economic operation, it would appear that, on the basis of electric power installations, beneficial economy is achieved in the region of 300-400 megawatts of electrical power output. For the present assessment of heat requirements, this would be equivalent to about 1000 to 1350 megawatts of heat, a value which is seen to lie midway in the range of water production and which, in fact, would be equal to a plant output of about 40 million gallons a day.

Taking this optimum size of nuclear reactor, it is interesting to assess the probable investment cost involved and also the annual operating charges in an attempt to forecast the operating costs per 1000 gallons of desalted water. These figures are calculated on the basis of a plant capable of producing 40 million gallons of fresh water a day.

Investment Charges

Capital cost of reactor-boiler ...	£33.25 million
Capital cost of evaporator, heat exchanger, pumps, etc.	6.00 „
Fuel investment in plant (taken as £4000 per MW of heat)	4.76 „
	£44.01 million

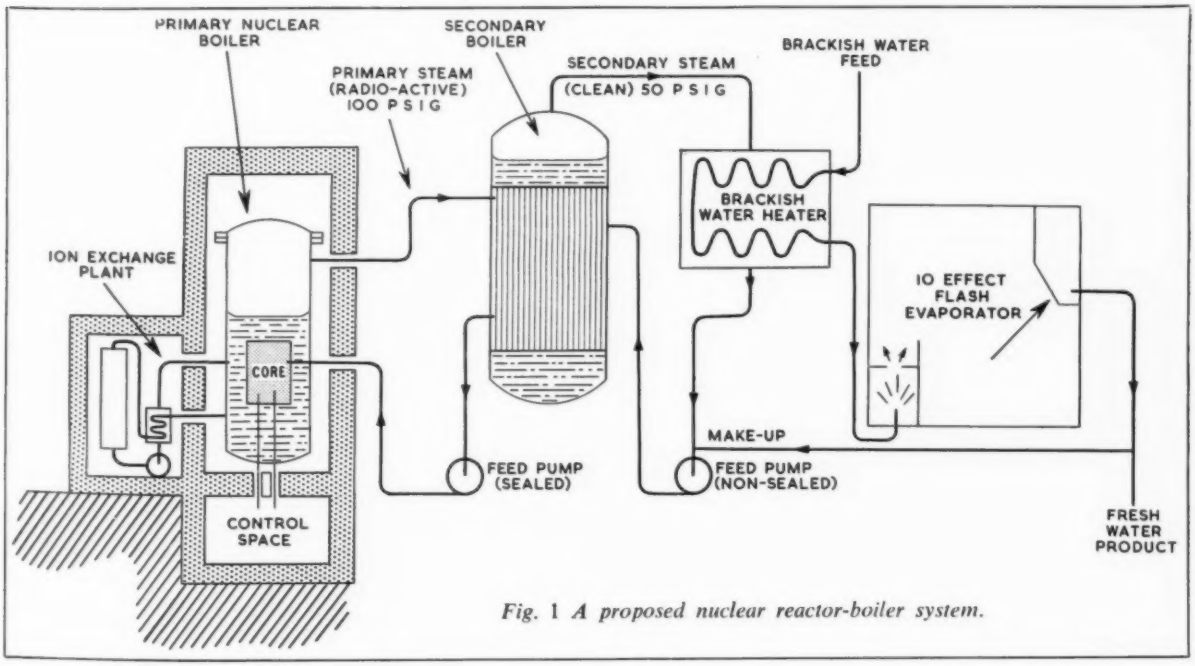

Fig. 1 A proposed nuclear reactor-boiler system.

Annual Charges

Capital (amortized over 20 years) ...	£2.20 million
Annual fuel rental (taken as 5% of initial fuel cost)	0.24 „
Operational labour	0.22 „
Separation of fuel	0.17 „
Fabrication of fuel elements	0.25 „
Pumping costs for condenser cooling water (taken at 5d for 1000 gallons)	0.21 „
	£3.29 million

Therefore, for an annual output of 14,690 million gallons (40.25 million gallons a day), the cost of water produced would be approximately 4.4s. per 1000 gallons.

This value would contrast very favourably with the present, most optimistic forecast of a cost of 7s. for 1000 gallons for a large vapour compression installation. It should, however, be noted that initial investment charges for a plant of equivalent output are very much higher in the case of a nuclear installation; in this particular example, approximately £44 million compared with £12 million.

As would be expected, the major influence on the cost of water produced is that due to the capital cost of the nuclear boiler. According to the data in the paper by Nicholls,[3] it would appear that capital costs rise very steeply for an installation below 150 megawatts of electrical output and this will greatly influence the cost of water produced. Fig. 2 illustrates this effect over a range of fresh-water outputs from 5.75 million up to 57.5 million gallons a day. Also indicated are the equivalent heat and electrical outputs of the nuclear boiler for the various water outputs. Fig. 3 illustrates the effect of size of plant on output cost.

Recent information from a paper by Lane,[4] gives some post-Geneva Conference costs for the more advanced types of reactor. Capital costs are much lower than those referred to in the earlier paper by Nicholls, and also fuel costs will be lower than those referred to in the previous example.

For a water output of 40 million gallons a day, capital cost may be reduced to £26.25 million and fuel investment to £3 million. The effect on the annual charge will be to reduce this to £2.76 million, giving a cost of water produced of approximately 3.5s. per 1000 gallons. Due

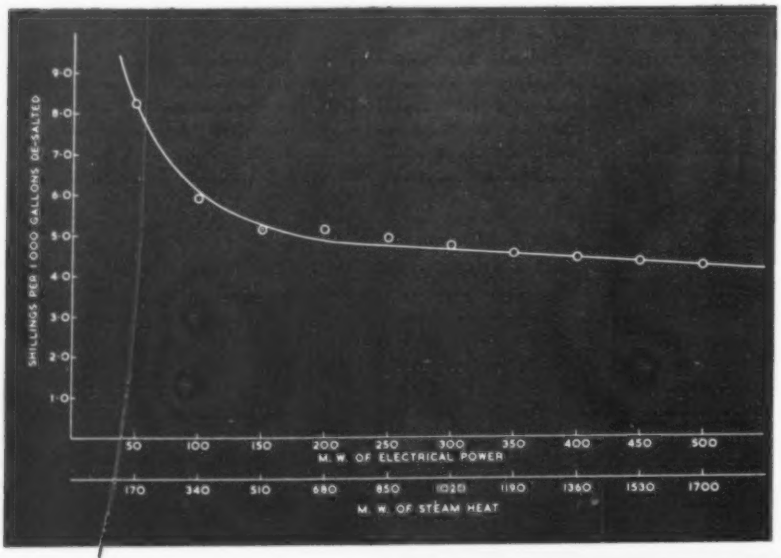

Fig. 2. The effect on the cost of fresh water production, due to the influence of the output of the nuclear boiler and capital cost (based upon data in the paper by Nicholls).

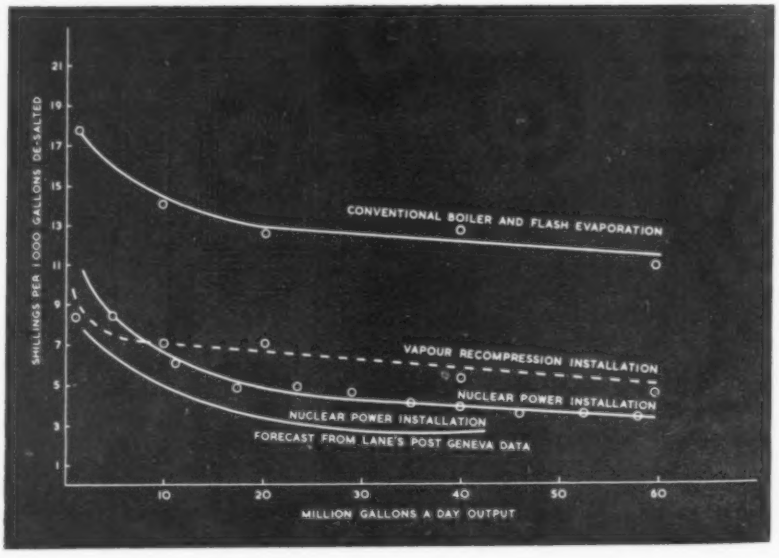

Fig. 3. Assessment of the probable desalting costs v. output.

to the shift in the capital-cost curve given in the paper by Lane,[4] it is even more interesting to note that size of reactor versus cost per kW of power has now shifted to an optimum electrical capacity of 160 MW compared to the earlier quoted value of 350 MW. This means, in terms of cost, water production at 3.5 to 3.8s. per 1000 gallons at a plant capacity of only 20 million gallons a day, compared to the previous optimum plant capacity of 40 million gallons a day. A reduction in the capital cost of the reactor to £13 million would be possible and also a corresponding reduction in fuel investment costs. The trend of this more recent curve is shown on Fig. 3.

Solvent Extraction Techniques

This process, details of which were given in an earlier paper on water purification techniques,[1] is, in essence, the use of a solvent to extract the fresh from salt or brackish waters. The solvent used must also be capable of giving up the fresh water when the liquid undergoes a rise in temperature. This process can only become competitive, and, indeed, feasible, if it is operated on a very large scale. Liquid flows and volumes would undoubtedly be large, as also would be the quantity of heat required for: (a) the separation of the water/solvent phase and (b) in auxiliary plant for the recovery and purification of the solvent. The most optimistic forecast for this process has indicated a cost in the region of 10s. per 1000 gallons and it will be interesting to see whether the application of heat and power from an atomic reactor might offer future possibilities. A schematic flow diagram of this process was given in Fig. 12 of the author's original article.[1]

Taking a similar capacity unit to that considered for an evaporation process as a basis of comparison, the output of desalted water would therefore be 40 million gallons a day or, very approximately, 1.7 million gallons an hour. Heat requirements for raising the temperature of the solvent/water extract, assuming 85% effective heat recovery in some form of counter-current system, will be of the order of 91.8 million Btu an hour or, in pounds of steam, approximately 91,800 lb. steam an hour. This, related to the size of an atomic boiler, would only be equal to one of 8 to 9 megawatts electrical capacity and, therefore, on the basis of later data supplied by Nicholls,[2] would not be an economic proposition. Therefore, for this particular method of water desalting, even on the scale envisaged, it would be considerably more economic to use some form of conventional steam-raising plant as a source of heat energy.

Conclusions

From the very brief survey of the possibility of using atomic energy in connection with large-scale water desalting, it would appear that, for an installation of the order of 40 million gallons a day output, the use of heat from some form of nuclear boiler, coupled with a more or less conventional multistage flash-type evaporator, is an intriguing possibility. It is not considered, however, that other methods of water purification could make use of such a reactor.

The article has been confined to the possibility of using this energy directly as heat, and has not considered the more obvious possibilities of using electrical energy from some form of atomic power station, as this would be a straightforward assessment based upon the prevailing costs of electrical power generation and supply. One other application, which again is a straightforward assumption, is that if an atomic power station were set up in some arid area, then one would also consider the merits of building into the installation some form of multi-effect flash or vapour recompression evaporator to make use of any low-grade waste heat that might be available. If such an installation were considered, then, of course, this might well be capable of producing fresh water at a cost far less than has been already mentioned. The immense volumes of cooling water that must be fed to the condensers of any power station, be it conventional or atomic powered, are a very obvious source of heat which is at the moment, sad to say, generally returned to the source from whence it came.

Acknowledgment is made to the United Kingdom Atomic Energy Authority for their permission to publish this paper. The information was prepared for, and presented at, the recent Harwell conference entitled "The Utilisation of Heat from Nuclear Reactors".

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[2] The possible costs given in the article for steam produced by a nuclear boiler are the result of information supplied by Mr. Nicholls, of Harwell, and discussions between Mr. Williams and Mr. Whitworth, of the Research and Development Department of Davey, Paxman & Co. Ltd., and the author.

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New Yorktown, Virginia, Refinery

THE recently completed Yorktown, Virginia, refinery of the American Oil Co. (Amoco Ltd.), which Kelloggs commenced designing in the spring of 1955, is described in an illustrated 16-page booklet* recently issued by the designers.

The Yorktown refinery is planned to process 35,000 barrels per stream day of crude oil. Finished products include branded and unleaded premium petrol, kerosene, fuel oil and coke. Surplus fuel gas is metered to the adjacent Virginia Electric Power Co. The plant includes a combination unit, hydrodesulphurisation unit, ultraformer and delayed coker. The combination unit includes an atmospheric-and-vacuum crude distillation section, a fluid catalytic cracking and gas-recovery section, a catalytic polymerisation section and a petrol and kerosene treating section. The catalytic cracker is of Kellogg's Orthoflow design. The plant has been integrated as completely as possible; intermediate tankage, for example, is available for unfinished products from various units, and this permits independent operation for limited periods. Even within the combination unit, various sections may be shut down and isolated while others operate. During normal operations, intermediate storage may be by-passed, so that the intermediate products are not cooled before leaving the units as is usually necessary when they are sent to storage. The process heat-input is therefore kept to a minimum.

Special attention is said to have been given during this stage to obtaining the optimum relationship between exchanger costs, and furnace- and steam-heating and water cooling. The in-line layout, resulting in parallel rows of towers and equipment, permits full use of mechanised equipment for erection, service and maintenance. Tractors may move freely through the unit.

The operation of an unusual kind of agreement between Amoco and the Virginia Electro Power Co. on the co-operative development of plant benefits Amoco in regard to cost of electric power, and the electricity company in respect of fuels (coke and excess fuel gas). In addition, a common cooling water forebay has been developed.

Crude oil, brought to the marine terminal by tanker, is pumped two and a half miles through a 24-in. pipe-line to crude storage. By using one long crude line, it was possible to shorten six product lines to the terminal.

* *Kelloggram*, 1957, No. 3.

SASOL:

WORLD'S LARGEST OIL-FROM-COAL PLANT

by J. C. HOOGENDOORN and
J. H. SALOMON, B.Sc. (Eng.) Ph.D.

The third article of this series* describes how the products of the Arge synthesis are worked-up with corresponding products of the Kellogg synthesis

AS mentioned in the previous article, a rough separation is effected between high and low boiling-product fractions by partial or stepwise condensation of the reactor products. The purpose of the Arge work-up section is: (1) to refine these primary products to final products of the required specifications; and (2) to separate these products which must be "worked-up" together with the corresponding products of the Kellogg synthesis.

Fig. 1 is a block diagram showing the principal flows in the Arge refinery. The core of the refinery is formed by the two distillation units—atmospheric distillation and high-vacuum distillation.

Atmospheric Distillation

Feed to the atmospheric distillation consists of the cold condensate, the oil fraction used for extraction of the catalyst, the hot condensate, the C_8+ fraction from the tail-gas recovery and recycle streams from the hot-refining, high-vacuum distillation and paraforming plants. To remove traces of organic acids formed in the synthesis reaction, the cold condensate, paraformed products and extraction oil are first washed with dilute caustic and a water after-wash. The combined feed is then continuously distilled into the following fractions:

(*a*) Overhead: petroleum to hot-refining plant
(*b*) Side: power paraffin
(*c*) Side: diesel oil
(*d*) Side: fuel oil
} to tank farm.
(*e*) Bottom: Waxy oil to high-vacuum distillation.

The distillation column, side strippers, etc., are of standard design. The feed is first preheated by heat exchange with the hot products and further heated in a gas-fired furnace. This furnace also supplies superheated stripping steam for the atmospheric column and the side strippers.

The vacuum distillation unit consists of three high-vacuum distillation towers and a stripping tower. The reactor wax, which still contains some medium-boiling hydrocarbons, is passed over a vacuum stripper to remove the hydrocarbons boiling under 320°C with stripping steam. The stripper has three heating elements as reboilers. Stripping steam is also used. The stripper vessel is divided into three compartments. Partly-stripped product from the first compartment overflows into the second compartment, where it is further stripped, and, finally, it overflows to the third stripping compartment, from where the stripped bottom products leave through the overflow pipe.

The stripped light hydrocarbons, after condensation, go to the combined feed of the atmospheric distillation unit.

The maze of pipes and tanks of the Arge product work-up section. The Arge reactors can be seen in the right background and the flare-stack, left.

The stripped wax now joins the bottom products of the atmospheric distillation and is passed into the first of the three vacuum towers. This tower produces an overhead fraction boiling between 320 and 370°C. The bottom product of the first tower goes to the second and third towers, which operate in parallel. The overhead product of these two parallel towers is the wax fraction 370-460°C, whereas the bottom product is unrefined hard wax, boiling point 460°C+.

Each high-vacuum distillation tower consists of a reboiler of special design, a rectifying tower with Raschig rings and a condenser built on top of it. The reboiler is constructed in a similar fashion to that of the wax stripper. Each heating element is surrounded by a baffle system to make it a more or less independent unit. The feed enters

* *The first article of this series was published in the May, 1957, issue of* British Chemical Engineering, *p.238. The second in the June issue, p.308.*

the first heating unit, outside the tubes, and is partly vaporised by the heat from the heating tubes and the stripping steam. Part of the vapours condense and form the reflux for the next heating element and so forth. At the last heating element, the bottom product of the unit leaves *via* an overflow. The vapours are rectified in the Raschig-ring-filled rectifying tower and condensed in the condenser. Part of the condensate is used as a reflux for the rectifying column; the remainder is withdrawn as product to the product tanks. A vacuum of 3 mm Hg—under no load conditions—is maintained by a double steam-ejector.

Hot, high-pressure water is used as the heating medium in the reboiler heating elements. The high solidification point and boiling point of the wax fraction makes water an unsuitable medium for cooling in the condensers. For this purpose, glycerol is chosen. This is circulated through the system and then heat-exchanged with cooling water.

Paraformer Plant

The paraformer (paraffin reformer) is a thermal cracking plant serving the following purposes: (1) It cracks hard wax to medium and soft wax. This makes the wax plant more flexible with regard to products. (2) It cracks the waxy oil-fractions into diesel oil and petrol. The plant consists essentially of a cracking furnace, an atmospheric and a vacuum distillation tower. The latter is only used in the wax-cracking operation. Products of the hard-wax cracking are mainly waxes of lower melting point, which are sent to the wax-hydrogenation plant, and some diesel oil and gasoline.

Hot Refining, Re-run and Stabilisation. The hot-refining plant is similar in its purposes to the "clay-treaters" in the Kellogg product-recovery section, viz.: (1) to convert oxygenates such as alcohols, aldehydes, etc., into hydrocarbons; and (2) to improve the octane rating of the petrol by shifting the double bond of the olefins from the end to the centre of the molecular chain. These changes are wrought by passing the petroleum vapours at 400°C over a fixed-catalyst bed. The plant consists of a furnace for feed heating, two refining reactors, a superheater to supply superheated steam for the steam-air mixture used for catalyst regeneration, and the necessary feed pumps. It is of standard design, with one reactor on stream while the catalyst in the second reactor is being regenerated by burning off the carbon deposit.

Hot-refined vapours are cooled down to about 70°C by heat exchange with the feed and are then distilled in the re-run column. The bottoms of this tower join the feed to the atmospheric column. The overhead vapours of the re-run column are condensed and are separated from the water formed in the hot-refining reaction. They are then passed to the stabilisation column, which is a normal 30-plate pressure column producing petrol of the required vapour pressure as a bottom product. The overhead vapours are condensed first with cooling water, and the non-condensibles of this first cooling stage are deep-cooled by liquid ammonia which produces more liquid product. The "fixed" gases from this stage go to the fuel gas system. The condensed overhead product serves as a feed to the catalytic polymerisation plant, together with the C_3 and C_4 fractions from the Kellogg refinery.

Two streams of waxes are obtained from the high-vacuum distillation unit. They consist of respectively a product boiling between 370-460°C and a product boiling above 460°C. These waxes are mainly paraffinic, but contain small amounts of olefins and oxygenates; they are, therefore, hydrogenated to convert all the non-paraffinic components into the corresponding paraffins. Hydrogenation is carried out in the liquid phase, over a fixed-catalyst bed, with pure hydrogen—in co-current stream. As the gas feed to the hydrocarbon synthesis plant is substantially free from sulphur, the synthesis products are uncontaminated by catalyst poisons. It is, therefore, possible to use highly-active hydrogenation catalysts. Three hydrogenation reactors are used. One system, consisting of one reactor, treats the 370-460°C stream (the distillate of vacuum distillation and wax fractions obtained in the paraforming of hard wax). The other system, which has two reactors, handles the hard-wax fraction, 460°C+. Operating conditions for both streams are, temperature approximately 500°F and 750 psi hydrogen partial pressure. Residence time is two to three hours.

The hard wax is a bottom product from the synthesis reactor and of the distillation units and may contain some mechanically entrained impurities. Before it is fed to the hydrogenation reactors, therefore, it is filtered through ceramic filters. The 370-460°C fraction is a distillate and does not need filtration. After hydrogenation, both fractions are passed, first over activated carbon and, finally, through ceramic filters. After this final filtration, the hard wax flows through an intermediate tank to a flaking machine, where it is flaked into final product by chilling it on a water-cooled rotating drum. The filtrate fraction 370-460°C is used as feed to the wax de-oiling plant.

The hydrogenated 370-460°C wax fraction consists of a mixture of soft wax, slab wax (medium wax) and some oil. In the de-oiling plant, oil-free waxes of the required melting points are produced. De-oiling is effected by extraction with a suitable solvent. The wax feed is mixed with the solvent and heated to about 60°C, so that a clear solution is obtained. This solution is then slowly cooled at a controlled rate in a scraper cooler. First, the high melting wax crystallises and the wax-crystal/solvent mixture is passed over a rotating filter. The wax-crystal cake is washed on the filter with oil-free fresh solvent, and the solvent is then further used for mixing with the wax feed. The first filtrate, containing lighter wax, oil and solvent, then goes to the next chilling stage in a scraper cooler with brine cooling. In this stage, the soft wax crystallises out and is also separated from the solvent on a rotary filter.

Both the medium-wax and soft-wax crystals are freed from solvent by heating, evaporation, vacuum distillation and atmospheric steam-stripping. The filtrate of the soft-wax separation is subject to an atmospheric and vacuum distillation to recover the solvent. The residual oil obtained in this regeneration forms a part of the feed stock for thermal cracking in the paraformer plant. Operation of the wax de-oiling plant is mainly controlled by adjustment of the temperatures. For a given feed, the wax yield increases with decreasing temperatures, whereas the melting point of the waxes produced increases with increasing temperatures. By choosing the right operating temperatures, it is possible to produce waxes of the required specifications.

Products. The layout of the Arge plant is very flexible. The synthesis produces a part of its hydrocarbons as very big molecules (about 50 C atoms per molecule) so that, together with the thermal-cracking plant (paraformer), a large range of products can be obtained. Some typical wax products are: Sasolwaks RG (congealing point, 203-206°F) and Sasolwaks MR (congealing point, 125-130°F). These are used for such widely differing purposes as the manufacture of paper cups—mainly in the United States—and the manufacture of floor polish. Waxes of intermediate congealing points are also made.

The Kellogg-products recovery section can be divided broadly into two subsections—for recovery of, respectively, (1) hydrocarbons, and (2) chemicals. These may be subdivided further as follows:

(*a*) Hydrocarbon recovery and working-up section.
(*b*) Catalytic-polymerisation (Cat.-Poly.) section.

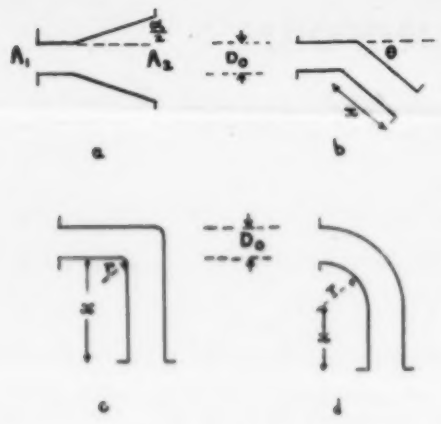

Fig. 1—TABLE I. Values of N_0 for Various Types of Inlet Connection at Different Velocities

(a) Diffuser $\frac{A_f}{A_1} >$ 5.					
a	16	20	30	60	> 60
N_0	4	5	6	10	$\approx \left(\frac{A_f}{A_1}\right)^2$
(b) Sharp 45-degree bend.					
x/D_0	0-1.0	3.0	>5		
N_0	1.35	1.25	1.05		
(c) Sharp 90-degree bend.					
x/D_0	1.2	3.0	6.0	>10	
N_0	3.5	2.8	1.3	1.05	
(d) Swept 90-degree bend.					
x/D_0	0-0.5...	1.0	2.0	3.0	>4
N_0	1.8	1.4	1.2	1.1	1.05

A_f = area of spread of jet, m²
f_p = loss coefficient for flow-smoothener obtained from Equation (1), (1a) or (4).

Systems of Flat Grids

Flat grids are more successful as gas-distributing devices when several are used in series instead of singly (Fig. 4). The number of grids, N_g, required for a given case can be determined by means of the following expressions:

$$N_g > 0.33 \frac{A_v}{A_f} \sqrt{N_0} \quad \ldots . (6)$$

which refers to side entries, whereas for central feed connections

$$N_g > 0.16 \frac{A_v}{A_f} \sqrt{N_0} \quad \ldots . (7)$$

If several grids are used in series, their free areas should be identical, in which case their loss coefficients can be determined by

$$f_p = N_0 \left(\frac{A_v}{A_f}\right)^{2/N_g} - 1 \quad \ldots . (8)$$

The amount of spread of flow brought about by each grid can be estimated from the relation

$$\frac{A_{ng}}{A_v} = \frac{A_v}{A_f} \left(\frac{\sqrt{1+f_p}}{N_0}\right)^n \quad \ldots . (9)$$

where A_{ng} represents the area of spread at the nth plate or grid. The optimum spacing for grids in series lies between 0.15 to 0.20 D_1, where D_1 is the characteristic dimension of the vessel's cross-section (diameter or largest side).

It should not be concluded from the foregoing that an increase in resistance in a system will lead automatically to uniform flow within the system. For example, a single inlet without additional means can provide uniform conditions although, generally, a construction which permits such an achievement will seldom be an economic one.

A single jet will spread out gradually until its flow pattern is practically uniform. The jet fluid in the process of spreading mixes with the stagnant or slowly moving fluid surrounding it. By transfer of momentum, the latter is accelerated in the direction of flow and, as mixing proceeds, so the central high-speed core diminishes and finally disappears. At this point the flow will be substantially uniform, but the process requires space for its completion. If an obstacle or obstacles are placed in the path of the jet and not coaxially with the core or orifice, then the jet may be caused to spread out rapidly. However, as we have seen from Fig. 2, a distortion of flow occurs at some distance downstream of a resistance, so that the purpose of installing such a device is defeated.

For this reason, a perforated plate or other smoothing device should not be situated too far from the face area at which uniformity of flow is required. For example, it would be a mistake to fit a grid at a considerable distance from the elements of an electro-precipitator. The best results would be obtained by placing it close to the elements.

There are other pitfalls which the designer must avoid when using smoothing devices, especially in cases where the smoothing process is followed by a further one wherein solid matter is being separated from the fluid. For example, with a multi-cyclone type of dust separator, the smoothing device might give rise to centrifugal effects—due to sharp changes in direction of flow—capable of producing a higher-than-average concentration of dust around a very small proportion of the total number of cyclone elements.[5]

Using Guide Baffles or Vanes

If the inlet to a vessel is at some angle to the direction of flow in the vessel and its cross-section is equal to that of the vessel, an effective method of flow equalisation can be obtained by the use of guide vanes as shown in Figs. 6 and 7. This method will not lead to any local concentrations of suspended material in the main fluid stream.

The procedure for designing a blade assembly is as follows. Each blade is made of sheet metal with a cylindrical surface whose length is equal to one-quarter of the circumference of the cylinder.[1] The optimum or minimum number of blades is then calculated from the following simple formulæ:

$$n_{opt} = 1.4 \frac{S}{t} \cong 1.4 \frac{S}{kD_0} \quad \ldots . (10)$$

$$n_{min} = 0.9 \frac{S}{t} \cong 0.9 \frac{S}{kD_1} \quad \ldots . (11)$$

where $S = \sqrt{D_0^2 + D_1^2}$ = distance between the tips of internal and external angles of bend of gas flow at point of turn in gas flow, m; D_0 = side or diameter of inlet connection to vessel in the plane of change of direction of flow; D_k = side or diameter at cross-section of vessel; $t = kD_0$, chord of blade; and k = a coefficient varying from 0.25 to 0.5 according to the dimensions of the vanes. When the chord of the blade is large k is also large, but the number of blades decreases as k increases and vice versa.

A construction with a number of blades determined from Equation (10) will have a more uniform velocity profile than one obtained by means of Equation (11). In some cases, however, it is enough to use the smaller number of blades, especially in the following cases in which additional smoothing devices are provided.

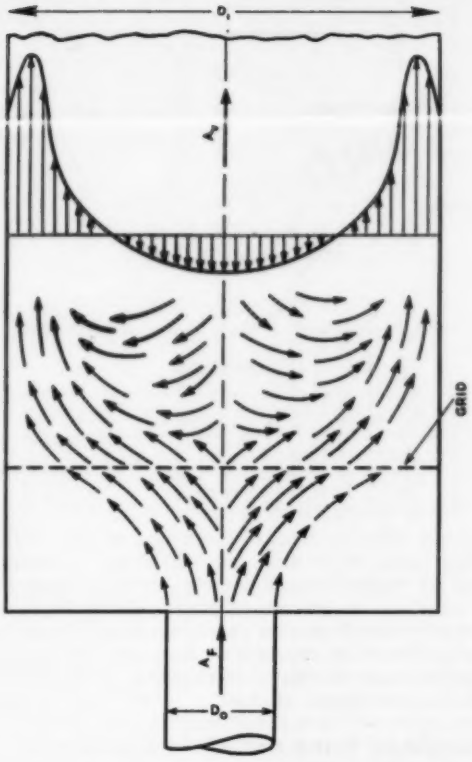

Fig. 2. Diagram illustrating distortion of flow downstream of grid.

The arrangement of blades at the plane where the flow changes direction is such that their distance apart is given by the following expressions:

$$\text{For optimum number of blades, } d_1 = 0.67\frac{S}{n_0+1}\left(1+\frac{i-1}{n_0}\right) \quad \ldots\ (12)$$

$$\text{For minimum number of blades, } d_1 = \frac{S}{n_m+1}\left(0.5+\frac{i-1}{n_m}\right) \quad \ldots\ (13)$$

where i is the number of the spacing between two adjacent blades starting with the space between the blade and the wall as 1.

For an ordinary bend or elbow with a small $D_1:D_0$ ratio, say of the order of 0.7 to 1.5, the fitting of blades in the bend presents little difficulty. In this case the distance of the first vane from the side of the trunking is based upon the inner surface of the blade, whereas the distance between succeeding blades is based upon their outer surfaces. In the case of a sharp elbow, the extreme distances are measured from the inner and outer angles of the bend respectively. The extreme spacings are readily calculated from the following formulæ:

$$d'_1 = d_1 - z$$
$$d'_{n+1} = d_{n+1} + z,$$

where z is the camber of a vane (see Fig. 5).

In the case where the ratio $D_1:D_0$ of a right-angle inlet to a vessel is very large, then the procedure for the design of the blades system may be as shown in Fig. 6.

The angle of incidence, α, may be obtained from Table III for different $D_1:D_0$ ratios.

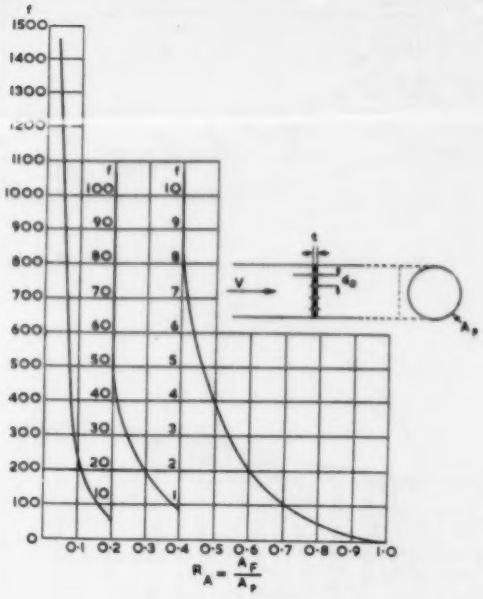

Fig. 3—TABLE II. Loss Coefficient for Grids where $\frac{t}{d_0} < 0.5$

R_a	0.02	0.03	0.04	0.05	0.06	0.08	0.10	0.12	0.14
f_p	7050	3100	1440	1075	732	398	247	165	117
R_a	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32
f_p	86	66	52	41	32	27	22	18	16
R_a	0.34	0.36	0.38	0.40	0.43	0.47	0.50	0.52	0.55
f_p	13	11.5	9.6	8.3	6.6	4.9	4.0	3.5	2.8
R_a	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.0
f_p	2.0	1.4	0.97	0.65	0.42	0.25	0.13	0.05	0.0

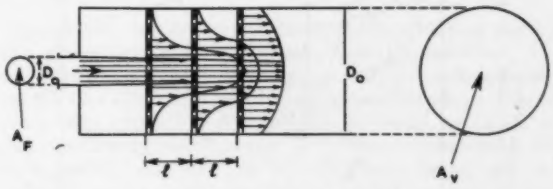

Fig. 4. A system of grids in series.

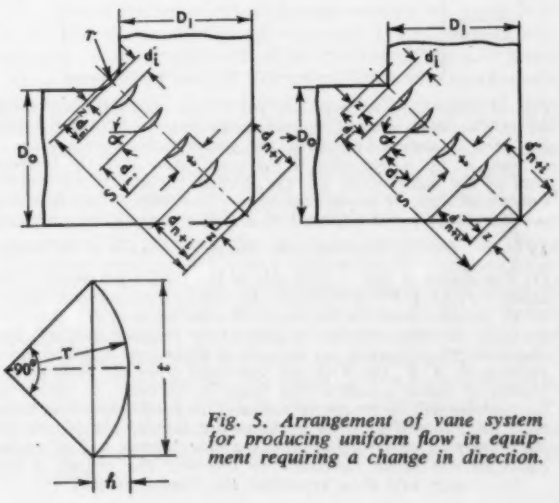

Fig. 5. Arrangement of vane system for producing uniform flow in equipment requiring a change in direction.

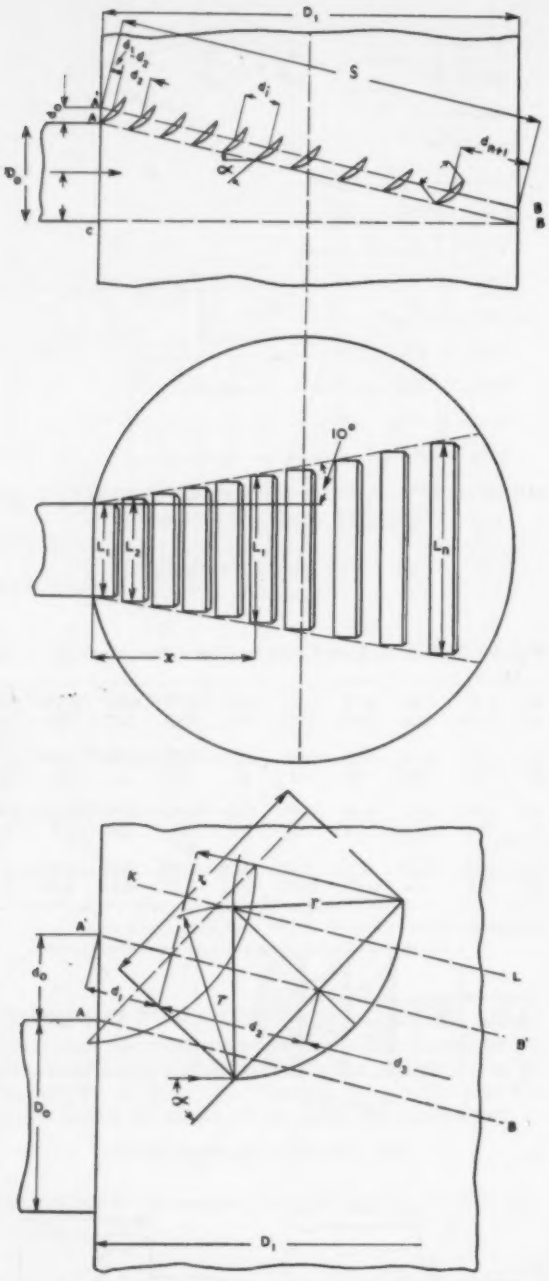

Fig. 6. Guide vane arrangement for vessels with relatively small inlets. The method of laying out the vanes is as follows: (1) *The line A-B is drawn by joining the points formed by the intersections of the upper edge of the supply duct with the internal wall of the main vessel and the internal section of the vessel's outer wall with the lower edge of the feed connection.* (2) *A line A'-B' is drawn parallel to the line A-B at a vertical distance equal to* $\frac{t}{3}\sin\alpha$ *from it. This line is the join of the centres of the blades.* (3) *The distances between chords of the blades are marked out along the line A'-B'.* (4) *Through the ends of the various divisions,* d_1, d_2, d_3, *etc., made in the line A-B, chordal lines are drawn at an angle* α *to the direction of flow of the entering fluid.* (5) *The chord length is marked out on each of these lines with the chord centres on A'-B'.* (6) *Arcs are described from the ends of the chords of radius equal to the blade curvature. The points of intersection will be the centre points of the blade curved surfaces; their join, line K-L, is then the centre line of the blades.* (7) *Arcs are now described from the above centres and of radius equal to the blade curvature to intersect the chords. These arcs will then represent the blades proper.*

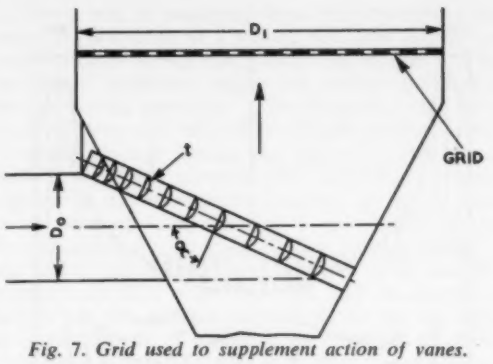

Fig. 7. Grid used to supplement action of vanes.

TABLE III

$D_1:D_0$	$\alpha°$	$D_1:D_0$	$\alpha°$
1.0	48±2	5.0	57±3
1.3	51±2	10	60±3
2.0	53±2	20	70±3

A less effective method is the use of flat instead of curved plates. With these, the best angle of incidence is about 85 degrees. Spacing of flat plates is determined in the same way as for curved plates. Where the inlet connection is much smaller than the vessel diameter, for example when the ratio $D_1:D_0$ is greater than 10-20, it is often necessary to use a combination of devices to get uniform distribution of flow.

Combined Vane and Grid Systems

Such systems are worth installing when the designer not only aims at a uniform velocity profile but also when he wishes to avoid swirling effects. The latter effects are sometimes generated downstream of a vane arrangement, especially where large ratios of $D_1:D_0$ exist.

When a vessel has a small inlet, the entering fluid leaves the connection in the form of a small jet and, generally, it will spread out in the form of a cone with an apex angle of about 20 degrees. This fact may be taken into account when designing flow-smoothing systems using vanes. The usual method is to give the blade a variable length, starting with the smallest size near the feed inlet and increasing it the further one proceeds from it. The dimensions of any particular blade are given by:

$$L = D_0 + 2\,x\tan 10°$$
$$= D_0 + 0.35\,x.$$

x = distance from feed inlet (see Fig. 7).

If a grid is chosen to supplement a vane system, then its dimensions may be obtained from the formulæ already given. In Equation (1), however, the product of D_0 and D_1 is substituted for A_f. Similarly, the value of N_0 in Equations (1) and (1a) is 1.5 for cambered guide plates and approximately 2.0 for flat plates.

Grid Fitted at Chamber Inlet

From a practical point of view, the combination formed by an expanding inlet, grid and guide-blade system, as shown in Fig. 10, is both effective and simple. Here the inlet opening is made equal in diameter to that of the working chamber. The feed inlet expands to its maximum cross-section quite sharply and within a distance equal to the diameter of the unexpanded portion D_r.

In order to secure uniform velocity distribution throughout the whole cross-section of the inlet opening, the distributing plate or grid has to be situated at a distance (d_0) not less than 0.6 D_0 from the plane at the inlet transverse to the main flow.

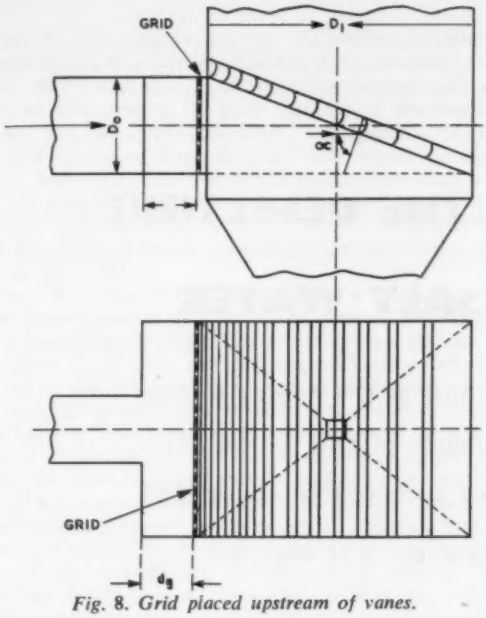

Fig. 8. Grid placed upstream of vanes.

To determine the dimensions of a grid using the equations previously given, A_v is taken to be the area of the inlet opening to the chamber and A_f the area of the narrow part of the feed inlet.

For uniform velocity distribution over the whole cross-section of the main vessel, guide vanes, curved or flat, can be fixed at a position in the vessel where the flow changes direction, using the methods already described.

Smoothing Flow by Means of Dividing Walls

In some apparatus the supply of fluid is made through a smoothly-expanding connection (diffuser). In such cases, when the use of long narrow-angled conical-diffusers is precluded, short wide-angled diffusers, provided with internal dividing walls, may be used as shown in the example given in Fig. 9 which is designed for a cone angle of 60 degrees. At present there is little design data for such guide walls, and the recommendations of Table IV must be regarded as approximations only.

TABLE IV. Number of Guide Walls and their Angles of Inclination for Diffusers of Different Angles

Included angle of diffuser, $a°$	Number of dividing walls, n_w	Overall angles of walls $a°_1$	$a°_2$	$a°_3$	$a°_4$
45	4	13	9	7	0
60	4	20	13	7	0
90	6	23	16.5	10	7

A method for the design of dividing walls is given in Fig. 9. Dividing walls by themselves will not produce a completely uniform flow of fluid throughout a vessel; indeed, they give only a partial smoothing effect. If a more uniform condition is required, then, in addition, a grid must be placed downstream of the diffuser and its guide walls.

At present there is some difficulty in designing supplementary grids because of the uncertainty of the effect of guide walls. However, a good general rule is to assume that the dividing walls cause a threefold spread of flow, so that in Equation (1) or (1a) the appropriate value of A_f should be three times the cross-sectional area of the narrow part of the inlet.

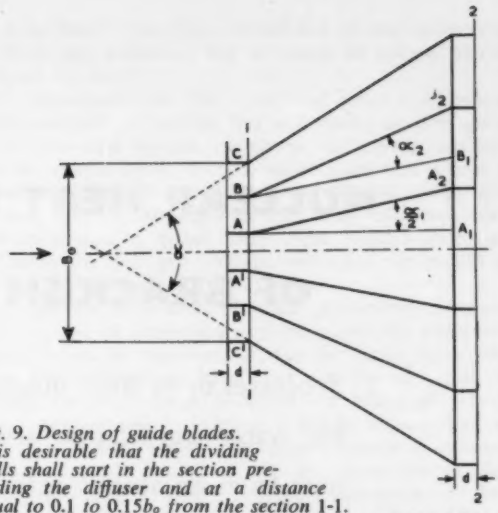

Fig. 9. Design of guide blades. It is desirable that the dividing walls shall start in the section preceding the diffuser and at a distance equal to 0.1 to 0.15b_0 from the section 1-1. They should finish at the same distance from section 2-2 in the straight part of the outlet. These straight sections of the dividing walls are made parallel to the axis of the diffuser. (1) The width of the inlet section of a diffuser is divided into n_1+1 equal sections AB, A'B', and so on. (2) the line A-A_1 is drawn parallel to the axis of the diffuser. (3) The line A-A_2 is drawn at an angle $\alpha_1/2$ to the line A-A. The first line gives the position of the dividing wall. (4) Another line B-B_1 is drawn parallel to the first dividing wall. (5) The line B-B_2 is then drawn at an angle α_2 to the line B-B_1. The former line gives the position of the second dividing wall. The positions of the remaining walls are fixed in the same way.

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Gas Production in Great Britain

THE AMOUNT OF gas made available in Britain during the nine months ended December, 1956, increased by 1.5% to 2044 million therms, according to statistics recently issued by the Gas Council. The quantity of surplus gas purchased from coke ovens and oil refineries increased by 12.8% to 340.5 million therms. However, the amount of coal-gas made increased by only 0.3% to 1474.2 million therms and the make of water-gas decreased by 6.7% to 204.7 million therms, so that the total production of coal- and water-gas was down by 0.5%. During the nine months, 19,611 thousand tons of coal were carbonised for gas making, an increase of 0.4%. For the production of water-gas 770.2 thousand tons of coke (−5.4%) and 66.5 million gallons of gas and heavy oil (a decrease of almost 10%) were used. The by-products of the industry all showed an increase—the amount of coke was 8989 thousand tons (+0.4%), of crude tar 1418 thousand tons (+1.3%), and of crude benzole 21.8 million gallons (+4.8%). The new plant brought into use during the period of the report had a daily capacity of 77 million cu. ft of gas, an increase of 20% over the figure for the corresponding part of the previous year. Of this equipment, carbonising plant was responsible for 40.1 million cu. ft, and showed an increase of 44.2% over the previous figure. 1602 miles of mains were laid—350 miles fewer than in the previous period. Industrial consumption of gas rose by 2.1% to 541.8 million therms, but domestic consumption fell by 0.4% to 964.7 million therms. The average revenue per therm of gas sold increased by 9.3% to 18.98d. At the end of January, 1957, the gas industry employed 139,941 persons, of whom 103,126 were operatives. The total was 1.6% less than a year previously.

NUCLEAR HEAT FOR THE DESALTING OF BRACKISH OR SALT WATER

Processes using large quantities of heat as the energy source for water purification are the subject of this article. The heat from an atomic reactor is one such source considered

by J. LEICESTER, M.I.Chem.E., A.I.Mar.E.*

FRESH water supply is a factor of major importance in the life of the community, and in many cases may be the deciding factor as to whether industrial or agricultural development of an area can take place. With rising living standards and increased industrialisation, it is becoming ever more difficult to find enough fresh water to meet demand. In the U.S.A. and throughout Europe the problem is being actively tackled, while in the British Commonwealth it is also being realised how development schemes may be delayed due to the fact that the only water available is brackish or salt water. The solution of these problems is an international task, and experimental and development projects are in progress in several countries which are directed towards one ultimate goal, the provision of fresh water in quantity and at an economic cost, wherever it may be required.

In this article it is intended to consider only those processes that use large quantities of heat as the energy source for water purification, namely distillation and solvent extraction techniques, and to examine the possibility of the use of heat supplied from some form of atomic reactor. In this respect, the problem can only be examined on the premise of information provided by the experts at Harwell and endeavour, assuming certain basic information, to translate this into probable costs for the large-scale desalting of water.

A typical figure for water usage per person a day is of the order of 1500 gallons, inclusive of agriculture, industry and domestic requirements. For a community of only 50,000 people, this would require a water supply of some 75 million gallons a day. The current cost of this water for all purposes amounts to an average figure of 0.8d. per 1000 gallons for irrigation, 2s. 8d. per 1000 gallons for domestic needs, and 2s. 3d. per 1000 gallons for industrial usage. These figures are only a very rough guide as to the cost level that may have to be taken into account when desalting brackish or salt water supplies. It will readily be appreciated that the figures apply to an area where the normal services of civilisation are in existence. For undeveloped areas, where there may be valuable potential development envisaged if fresh water were available, then the costs might easily be multiplied by a factor of 10, and still prove of sufficient interest to warrant consideration of methods of water purification. In certain of our colonial territories, costs of from 40s. up to as high as 400s. per 1000 gallons are being charged for supplies of fresh water.

From an earlier article,[1] it will be noted that it has been already forecast that for large-scale production units of the order of 1 million gallons a day output the lowest cost for vapour recompression methods is of the order of 7 to 7.5s. for 1000 gallons according to the desalting range. For multi-stage flash evaporators, the cost is not expected to drop below 16s. per 1000 gallons and for solvent extraction methods a forecast of 10s. per 1000 gallons is given.

Evaporation Techniques

When considering processes involving the purification of water by evaporation and recondensation of the vapour, it is obvious that the operating locality can greatly influence the type of plant and ultimate cost of water produced. For instance, if a development scheme is considered which envisages the use of steam and cooling water as part of a major process plant, then obviously it would be prudent to use any available process or pass-out steam in some form of multi-effect or flash-type evaporator plant. If, however, a situation arose where steam and cooling water were not available either at all or in sufficient quantity to support a development scheme, then consideration would have to be given to the self-contained, diesel-driven vapour-compression evaporator which requires no external source of heat or cooling water. Again, one must consider other methods of evaporation dependent upon the climatic and geographical conditions of the development area. Is the amount of sunshine a year sufficient to make solar evaporation an attractive method, or are there other geographical features available that would allow evaporation processes to be developed based upon thermal differences, either in the sea or inland lakes? All these factors must be assessed before it is possible to decide which particular process might best suit a development area.

In the light of present developments in the field of atomic energy, it is essential that we should also consider this source of heat to see whether it might become economic

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for use in connection with the distillation of salt or brackish water. It is conceivable that future atomic power plants will be built as part of the major colonisation and industrial development of areas that are at the moment sparsely populated or completely unpopulated. In this case, it is probable that low-grade heat would be available in large quantities. In addition, we must also consider the possible use of an atomic reactor as a direct source of heat for distillation. It is this application which offers the most intriguing possibilities for the future arid areas of the world.

If we are to consider the possibility of a nuclear reactor as the primary source of heat for an evaporation process, then it would appear logical to consider a system such as that shown in Fig. 1. Here, a nuclear-reactor boiler is assumed in which the primary steam is produced at about 150 psig. This steam (possibly slightly radioactive) is then passed to a secondary boiler or heat exchanger producing steam at about 50 psig. The non-radioactive steam produced from this secondary boiler would then be used in a more or less conventional design of evaporator. The other future possibility would be the design of a nuclear heating system that would directly heat the evaporating liquor in place of the less-efficient indirect-heating method. For safety and health reasons, this may be a more difficult design to envisage, and this assessment is based upon the indirect system of heating using a secondary heat exchanger.

The possible costs of steam produced by a nuclear boiler will obviously depend largely upon the capital costs involved, the steam output of the unit and also the pressure at which it is required to operate.[2]

In considering this application to large-scale fresh-water production, it is clear that it can only be of interest for very large capacity plants such as might be envisaged for the centralised purification and supply of water to a whole community. The following estimates, therefore, are based on a plant capable of supplying a minimum of 10 million gallons a day and up to a maximum of 100 million gallons a day. For the production of 10 million gallons a day and assuming the use of a 10-effect flash-type evaporator, this would require the supply of some 20 million pounds of steam a day or approximately 1 million pounds of steam an hour. This figure would rise to the upper limit of 200 million pounds a day or about 10 million pounds of steam an hour.

If it is assumed that 1000 pounds of steam is equivalent to approximately 1 million Btu and taking an average of the various cost figures calculated for steam produced from an atomic boiler, then it would seem that a cost of around 5s. per 1000 pounds can be achieved. This figure is based upon a 40-megawatt (in terms of steam heat) installation, and if larger units were feasible then, undoubtedly, the cost per 1000 pounds of steam would be reduced accordingly.

For the two parameters of water production, a reactor boiler capable of producing approximately 300 megawatts of heat would be required, or, for the larger unit, 3000 megawatts of heat an hour. From a recent paper by Nicholls,[3] in which was discussed the effect of size of reactor on economic operation, it would appear that, on the basis of electric power installations, beneficial economy is achieved in the region of 300-400 megawatts of electrical power output. For the present assessment of heat requirements, this would be equivalent to about 1000 to 1350 megawatts of heat, a value which is seen to lie midway in the range of water production and which, in fact, would be equal to a plant output of about 40 million gallons a day.

Taking this optimum size of nuclear reactor, it is interesting to assess the probable investment cost involved and also the annual operating charges in an attempt to forecast the operating costs per 1000 gallons of desalted water. These figures are calculated on the basis of a plant capable of producing 40 million gallons of fresh water a day.

Investment Charges

Capital cost of reactor-boiler ...	£33.25 million
Capital cost of evaporator, heat exchanger, pumps, etc.	6.00 „
Fuel investment in plant (taken as £4000 per MW of heat)	4.76 „
	£44.01 million

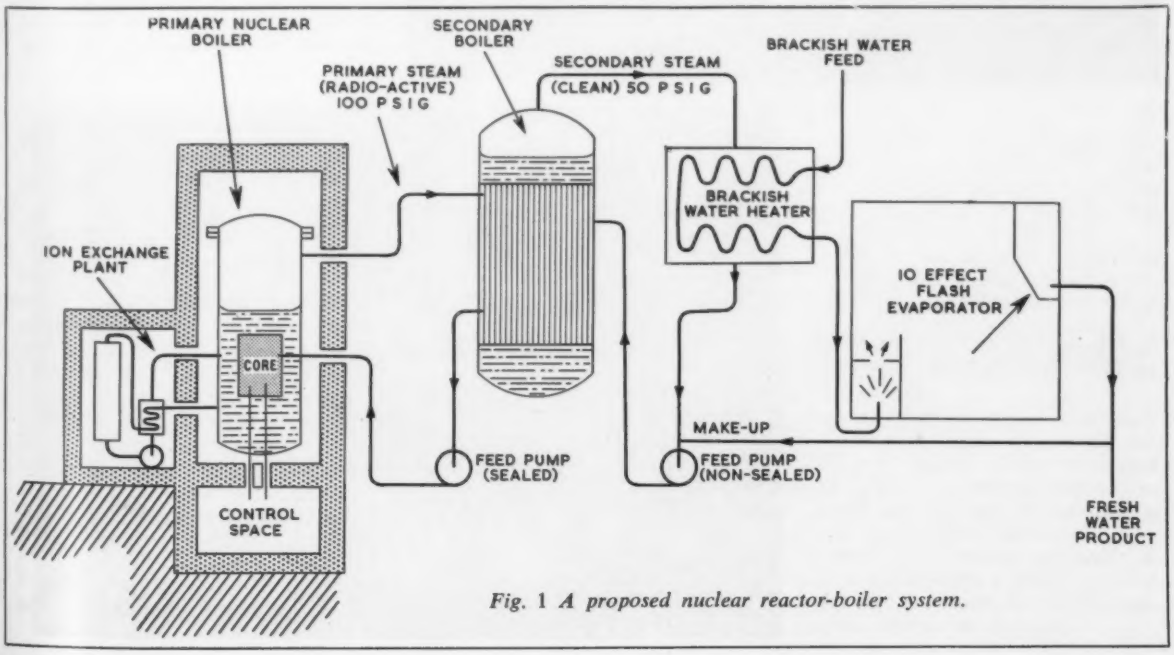

Fig. 1 A proposed nuclear reactor-boiler system.

Annual Charges

Capital (amortized over 20 years) ...	£2.20	million
Annual fuel rental (taken as 5% of initial fuel cost)	0.24	„
Operational labour	0.22	„
Separation of fuel	0.17	„
Fabrication of fuel elements	0.25	„
Pumping costs for condenser cooling water (taken at 5d for 1000 gallons)	0.21	„
	£3.29	million

Therefore, for an annual output of 14,690 million gallons (40.25 million gallons a day), the cost of water produced would be approximately 4.4s. per 1000 gallons.

This value would contrast very favourably with the present, most optimistic forecast of a cost of 7s. for 1000 gallons for a large vapour compression installation. It should, however, be noted that initial investment charges for a plant of equivalent output are very much higher in the case of a nuclear installation; in this particular example, approximately £44 million compared with £12 million.

As would be expected, the major influence on the cost of water produced is that due to the capital cost of the nuclear boiler. According to the data in the paper by Nicholls,[3] it would appear that capital costs rise very steeply for an installation below 150 megawatts of electrical output and this will greatly influence the cost of water produced. Fig. 2 illustrates this effect over a range of fresh-water outputs from 5.75 million up to 57.5 million gallons a day. Also indicated are the equivalent heat and electrical outputs of the nuclear boiler for the various water outputs. Fig. 3 illustrates the effect of size of plant on output cost.

Recent information from a paper by Lane,[4] gives some post-Geneva Conference costs for the more advanced types of reactor. Capital costs are much lower than those referred to in the earlier paper by Nicholls, and also fuel costs will be lower than those referred to in the previous example.

For a water output of 40 million gallons a day, capital cost may be reduced to £26.25 million and fuel investment to £3 million. The effect on the annual charge will be to reduce this to £2.76 million, giving a cost of water produced of approximately 3.5s. per 1000 gallons. Due

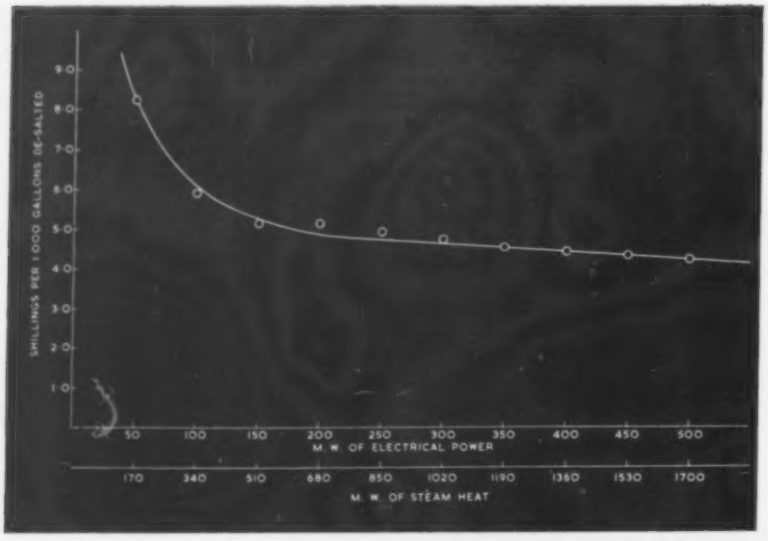

Fig. 2. The effect on the cost of fresh water production, due to the influence of the output of the nuclear boiler and capital cost (based upon data in the paper by Nicholls).

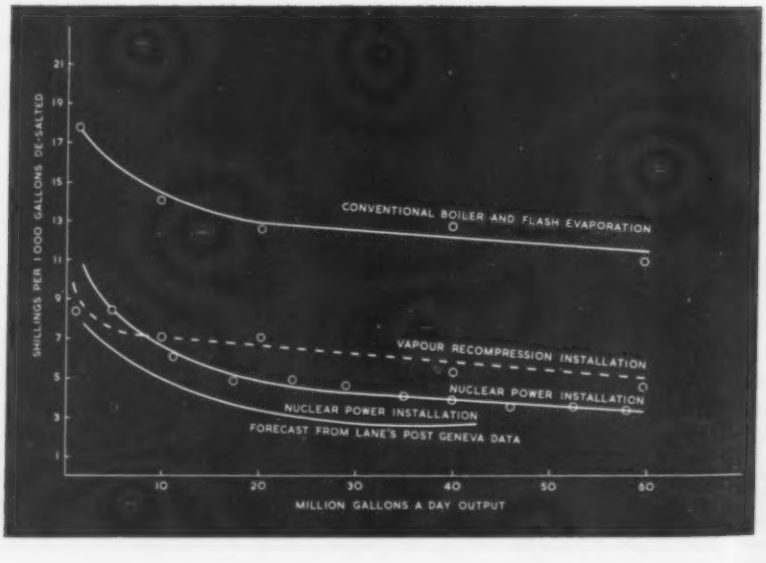

Fig. 3. Assessment of the probable desalting costs v. *output.*

to the shift in the capital-cost curve given in the paper by Lane,[4] it is even more interesting to note that size of reactor versus cost per kW of power has now shifted to an optimum electrical capacity of 160 MW compared to the earlier quoted value of 350 MW. This means, in terms of cost, water production at 3.5 to 3.8s. per 1000 gallons at a plant capacity of only 20 million gallons a day, compared to the previous optimum plant capacity of 40 million gallons a day. A reduction in the capital cost of the reactor to £13 million would be possible and also a corresponding reduction in fuel investment costs. The trend of this more recent curve is shown on Fig. 3.

Solvent Extraction Techniques

This process, details of which were given in an earlier paper on water purification techniques,[1] is, in essence, the use of a solvent to extract the fresh from salt or brackish waters. The solvent used must also be capable of giving up the fresh water when the liquid undergoes a rise in temperature. This process can only become competitive, and, indeed, feasible, if it is operated on a very large scale. Liquid flows and volumes would undoubtedly be large, as also would be the quantity of heat required for: (a) the separation of the water/solvent phase and (b) in auxiliary plant for the recovery and purification of the solvent. The most optimistic forecast for this process has indicated a cost in the region of 10s. per 1000 gallons and it will be interesting to see whether the application of heat and power from an atomic reactor might offer future possibilities. A schematic flow diagram of this process was given in Fig. 12 of the author's original article.[1]

Taking a similar capacity unit to that considered for an evaporation process as a basis of comparison, the output of desalted water would therefore be 40 million gallons a day or, very approximately, 1.7 million gallons an hour. Heat requirements for raising the temperature of the solvent/water extract, assuming 85% effective heat recovery in some form of counter-current system, will be of the order of 91.8 million Btu an hour or, in pounds of steam, approximately 91,800 lb. steam an hour. This, related to the size of an atomic boiler, would only be equal to one of 8 to 9 megawatts electrical capacity and, therefore, on the basis of later data supplied by Nicholls,[2] would not be an economic proposition. Therefore, for this particular method of water desalting, even on the scale envisaged, it would be considerably more economic to use some form of conventional steam-raising plant as a source of heat energy.

Conclusions

From the very brief survey of the possibility of using atomic energy in connection with large-scale water desalting, it would appear that, for an installation of the order of 40 million gallons a day output, the use of heat from some form of nuclear boiler, coupled with a more or less conventional multistage flash-type evaporator, is an intriguing possibility. It is not considered, however, that other methods of water purification could make use of such a reactor.

The article has been confined to the possibility of using this energy directly as heat, and has not considered the more obvious possibilities of using electrical energy from some form of atomic power station, as this would be a straightforward assessment based upon the prevailing costs of electrical power generation and supply. One other application, which again is a straightforward assumption, is that if an atomic power station were set up in some arid area, then one would also consider the merits of building into the installation some form of multi-effect flash or vapour recompression evaporator to make use of any low-grade waste heat that might be available. If such an installation were considered, then, of course, this might well be capable of producing fresh water at a cost far less than has been already mentioned. The immense volumes of cooling water that must be fed to the condensers of any power station, be it conventional or atomic powered, are a very obvious source of heat which is at the moment, sad to say, generally returned to the source from whence it came.

Acknowledgment is made to the United Kingdom Atomic Energy Authority for their permission to publish this paper. The information was prepared for, and presented at, the recent Harwell conference entitled "The Utilisation of Heat from Nuclear Reactors".

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New Yorktown, Virginia, Refinery

THE recently completed Yorktown, Virginia, refinery of the American Oil Co. (Amoco Ltd.), which Kelloggs commenced designing in the spring of 1955, is described in an illustrated 16-page booklet* recently issued by the designers.

The Yorktown refinery is planned to process 35,000 barrels per stream day of crude oil. Finished products include branded and unleaded premium petrol, kerosene, fuel oil and coke. Surplus fuel gas is metered to the adjacent Virginia Electric Power Co. The plant includes a combination unit, hydrodesulphurisation unit, ultraformer and delayed coker. The combination unit includes an atmospheric-and-vacuum crude distillation section, a fluid catalytic cracking and gas-recovery section, a catalytic polymerisation section and a petrol and kerosene treating section. The catalytic cracker is of Kellogg's Orthoflow design. The plant has been integrated as completely as possible; intermediate tankage, for example, is available for unfinished products from various units, and this permits independent operation for limited periods. Even within the combination unit, various sections may be shut down and isolated while others operate. During normal operations, intermediate storage may be by-passed, so that the intermediate products are not cooled before leaving the units as is usually necessary when they are sent to storage. The process heat-input is therefore kept to a minimum.

Special attention is said to have been given during this stage to obtaining the optimum relationship between exchanger costs, and furnace- and steam-heating and water cooling. The in-line layout, resulting in parallel rows of towers and equipment, permits full use of mechanised equipment for erection, service and maintenance. Tractors may move freely through the unit.

The operation of an unusual kind of agreement between Amoco and the Virginia Electro Power Co. on the co-operative development of plant benefits Amoco in regard to cost of electric power, and the electricity company in respect of fuels (coke and excess fuel gas). In addition, a common cooling water forebay has been developed.

Crude oil, brought to the marine terminal by tanker, is pumped two and a half miles through a 24-in. pipe-line to crude storage. By using one long crude line, it was possible to shorten six product lines to the terminal.

* *Kelloggram*, 1957, No. 3.

SASOL:

WORLD'S LARGEST OIL-FROM-COAL PLANT

by J. C. HOOGENDOORN and
J. H. SALOMON, B.Sc. (Eng.) Ph.D.

The third article of this series* describes how the products of the Arge synthesis are worked-up with corresponding products of the Kellogg synthesis

AS mentioned in the previous article, a rough separation is effected between high and low boiling-product fractions by partial or stepwise condensation of the reactor products. The purpose of the Arge work-up section is: (1) to refine these primary products to final products of the required specifications; and (2) to separate these products which must be "worked-up" together with the corresponding products of the Kellogg synthesis.

Fig. 1 is a block diagram showing the principal flows in the Arge refinery. The core of the refinery is formed by the two distillation units—atmospheric distillation and high-vacuum distillation.

Atmospheric Distillation

Feed to the atmospheric distillation consists of the cold condensate, the oil fraction used for extraction of the catalyst, the hot condensate, the C_8+ fraction from the tail-gas recovery and recycle streams from the hot-refining, high-vacuum distillation and paraforming plants. To remove traces of organic acids formed in the synthesis reaction, the cold condensate, paraformed products and extraction oil are first washed with dilute caustic and a water after-wash. The combined feed is then continuously distilled into the following fractions:

(*a*) Overhead: petroleum to hot-refining plant
(*b*) Side: power paraffin
(*c*) Side: diesel oil } to tank farm.
(*d*) Side: fuel oil
(*e*) Bottom: Waxy oil to high-vacuum distillation.

The distillation column, side strippers, etc., are of standard design. The feed is first preheated by heat exchange with the hot products and further heated in a gas-fired furnace. This furnace also supplies superheated stripping steam for the atmospheric column and the side strippers.

The vacuum distillation unit consists of three high-vacuum distillation towers and a stripping tower. The reactor wax, which still contains some medium-boiling hydrocarbons, is passed over a vacuum stripper to remove the hydrocarbons boiling under 320°C with stripping steam. The stripper has three heating elements as reboilers. Stripping steam is also used. The stripper vessel is divided into three compartments. Partly-stripped product from the first compartment overflows into the second compartment, where it is further stripped, and, finally, it overflows to the third stripping compartment, from where the stripped bottom products leave through the overflow pipe.

The stripped light hydrocarbons, after condensation, go to the combined feed of the atmospheric distillation unit.

The maze of pipes and tanks of the Arge product work-up section. The Arge reactors can be seen in the right background and the flare-stack, left.

The stripped wax now joins the bottom products of the atmospheric distillation and is passed into the first of the three vacuum towers. This tower produces an overhead fraction boiling between 320 and 370°C. The bottom product of the first tower goes to the second and third towers, which operate in parallel. The overhead product of these two parallel towers is the wax fraction 370-460°C, whereas the bottom product is unrefined hard wax, boiling point 460°C+.

Each high-vacuum distillation tower consists of a reboiler of special design, a rectifying tower with Raschig rings and a condenser built on top of it. The reboiler is constructed in a similar fashion to that of the wax stripper. Each heating element is surrounded by a baffle system to make it a more or less independent unit. The feed enters

* *The first article of this series was published in the May, 1957, issue of* British Chemical Engineering, *p.238. The second in the June issue, p.308.*

the first heating unit, outside the tubes, and is partly vaporised by the heat from the heating tubes and the stripping steam. Part of the vapours condense and form the reflux for the next heating element and so forth. At the last heating element, the bottom product of the unit leaves *via* an overflow. The vapours are rectified in the Raschig-ring-filled rectifying tower and condensed in the condenser. Part of the condensate is used as a reflux for the rectifying column; the remainder is withdrawn as product to the product tanks. A vacuum of 3 mm Hg—under no load conditions—is maintained by a double steam-ejector.

Hot, high-pressure water is used as the heating medium in the reboiler heating elements. The high solidification point and boiling point of the wax fraction makes water an unsuitable medium for cooling in the condensers. For this purpose, glycerol is chosen. This is circulated through the system and then heat-exchanged with cooling water.

Paraformer Plant

The paraformer (paraffin reformer) is a thermal cracking plant serving the following purposes: (1) It cracks hard wax to medium and soft wax. This makes the wax plant more flexible with regard to products. (2) It cracks the waxy oil-fractions into diesel oil and petrol. The plant consists essentially of a cracking furnace, an atmospheric and a vacuum distillation tower. The latter is only used in the wax-cracking operation. Products of the hard-wax cracking are mainly waxes of lower melting point, which are sent to the wax-hydrogenation plant, and some diesel oil and gasoline.

Hot Refining, Re-run and Stabilisation. The hot-refining plant is similar in its purposes to the "clay-treaters" in the Kellogg product-recovery section, viz.: (1) to convert oxygenates such as alcohols, aldehydes, etc., into hydrocarbons; and (2) to improve the octane rating of the petrol by shifting the double bond of the olefins from the end to the centre of the molecular chain. These changes are wrought by passing the petroleum vapours at 400°C over a fixed-catalyst bed. The plant consists of a furnace for feed heating, two refining reactors, a superheater to supply superheated steam for the steam-air mixture used for catalyst regeneration, and the necessary feed pumps. It is of standard design, with one reactor on stream while the catalyst in the second reactor is being regenerated by burning off the carbon deposit.

Hot-refined vapours are cooled down to about 70°C by heat exchange with the feed and are then distilled in the re-run column. The bottoms of this tower join the feed to the atmospheric column. The overhead vapours of the re-run column are condensed and are separated from the water formed in the hot-refining reaction. They are then passed to the stabilisation column, which is a normal 30-plate pressure column producing petrol of the required vapour pressure as a bottom product. The overhead vapours are condensed first with cooling water, and the non-condensibles of this first cooling stage are deep-cooled by liquid ammonia which produces more liquid product. The "fixed" gases from this stage go to the fuel gas system. The condensed overhead product serves as a feed to the catalytic polymerisation plant, together with the C_3 and C_4 fractions from the Kellogg refinery.

Two streams of waxes are obtained from the high-vacuum distillation unit. They consist of respectively a product boiling between 370-460°C and a product boiling above 460°C. These waxes are mainly paraffinic, but contain small amounts of olefins and oxygenates; they are, therefore, hydrogenated to convert all the non-paraffinic components into the corresponding paraffins. Hydrogenation is carried out in the liquid phase, over a fixed-catalyst bed, with pure hydrogen—in co-current stream. As the gas feed to the hydrocarbon synthesis plant is substantially free from sulphur, the synthesis products are uncontaminated by catalyst poisons. It is, therefore, possible to use highly-active hydrogenation catalysts. Three hydrogenation reactors are used. One system, consisting of one reactor, treats the 370-460°C stream (the distillate of vacuum distillation and wax fractions obtained in the paraforming of hard wax). The other system, which has two reactors, handles the hard-wax fraction, 460°C+. Operating conditions for both streams are, temperature approximately 500°F and 750 psi hydrogen partial pressure. Residence time is two to three hours.

The hard wax is a bottom product from the synthesis reactor and of the distillation units and may contain some mechanically entrained impurities. Before it is fed to the hydrogenation reactors, therefore, it is filtered through ceramic filters. The 370-460°C fraction is a distillate and does not need filtration. After hydrogenation, both fractions are passed, first over activated carbon and, finally, through ceramic filters. After this final filtration, the hard wax flows through an intermediate tank to a flaking machine, where it is flaked into final product by chilling it on a water-cooled rotating drum. The filtrate fraction 370-460°C is used as feed to the wax de-oiling plant.

The hydrogenated 370-460°C wax fraction consists of a mixture of soft wax, slab wax (medium wax) and some oil. In the de-oiling plant, oil-free waxes of the required melting points are produced. De-oiling is effected by extraction with a suitable solvent. The wax feed is mixed with the solvent and heated to about 60°C, so that a clear solution is obtained. This solution is then slowly cooled at a controlled rate in a scraper cooler. First, the high melting wax crystallises and the wax-crystal/solvent mixture is passed over a rotating filter. The wax-crystal cake is washed on the filter with oil-free fresh solvent, and the solvent is then further used for mixing with the wax feed. The first filtrate, containing lighter wax, oil and solvent, then goes to the next chilling stage in a scraper cooler with brine cooling. In this stage, the soft wax crystallises out and is also separated from the solvent on a rotary filter.

Both the medium-wax and soft-wax crystals are freed from solvent by heating, evaporation, vacuum distillation and atmospheric steam-stripping. The filtrate of the soft-wax separation is subject to an atmospheric and vacuum distillation to recover the solvent. The residual oil obtained in this regeneration forms a part of the feed stock for thermal cracking in the paraformer plant. Operation of the wax de-oiling plant is mainly controlled by adjustment of the temperatures. For a given feed, the wax yield increases with decreasing temperatures, whereas the melting point of the waxes produced increases with increasing temperatures. By choosing the right operating temperatures, it is possible to produce waxes of the required specifications.

Products. The layout of the Arge plant is very flexible. The synthesis produces a part of its hydrocarbons as very big molecules (about 50 C atoms per molecule) so that, together with the thermal-cracking plant (paraformer), a large range of products can be obtained. Some typical wax products are: Sasolwaks RG (congealing point, 203-206°F) and Sasolwaks MR (congealing point, 125-130°F). These are used for such widely differing purposes as the manufacture of paper cups—mainly in the United States—and the manufacture of floor polish. Waxes of intermediate congealing points are also made.

The Kellogg-products recovery section can be divided broadly into two subsections—for recovery of, respectively, (1) hydrocarbons, and (2) chemicals. These may be subdivided further as follows:

(*a*) Hydrocarbon recovery and working-up section.
(*b*) Catalytic-polymerisation (Cat.-Poly.) section.

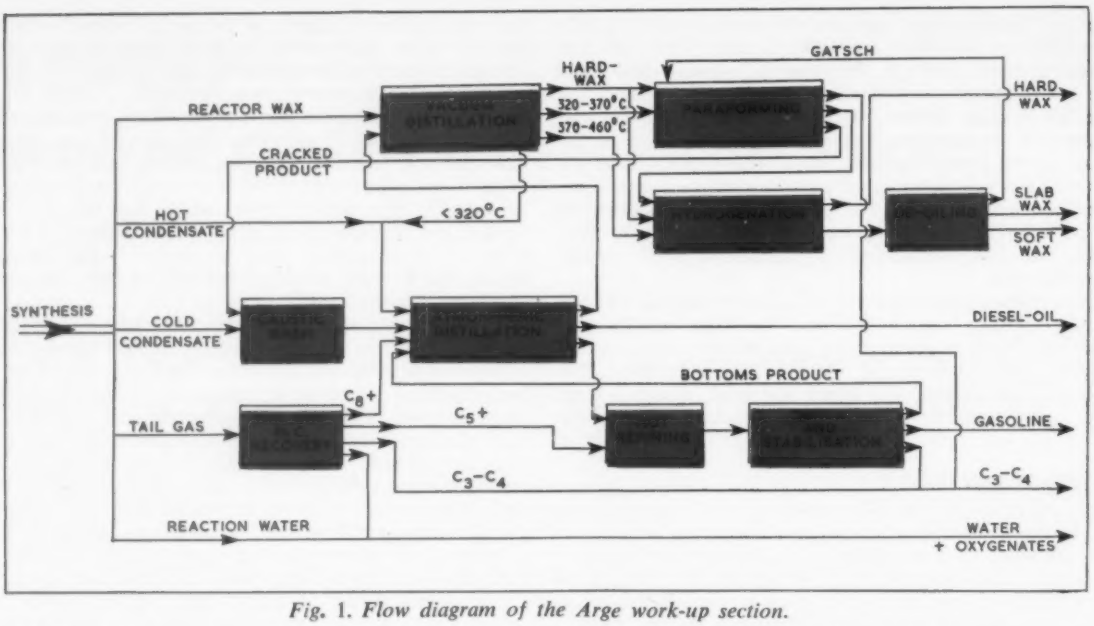


Fig. 1. Flow diagram of the Arge work-up section.

(*c*) Chemicals recovery section.

(*d*) Solvent recovery section (see Fig. 3).

Although these sections will be dealt with, as far as possible, under these last headings, it should be understood that (*a*) and (*b*) as well as (*c*) and (*d*) are interrelated and interdependent.

Kellogg Products Recovery

(*a*) *Hydrocarbon Recovery and Working-up Section.* In this section (see Fig. 2) the liquid and gaseous hydrocarbon streams from the synthesis are treated to produce useful, saleable products. The liquid streams from the synthesis are treated at a low pressure and a high temperature by contact with a silica-alumina catalyst in a fixed-bed reactor in the vapour phase. Before this treatment can be carried out, the decanted oil from the scrubber tower must be prepared. As it comes from the scrubber, it contains some iron and other metal contaminants as well as very high boiling components which would not vaporise even at the temperatures obtained in the "clay-treaters". These must be removed before the oil is treated further.

The oil is preheated to about 450°F by superheated steam and is then fed into a vacuum flash tower operating under a pressure, in the flash zone, of about 1.5 psia. Stripping steam is injected to the bottom of the tower, and the reflux rate to the tower is controlled so that all hydrocarbons boiling below about 650°F should distil over. The stripping steam condensate is drawn off from the reflux drum to drain. The distillate from the vacuum flash tower is mixed with the light oil from the oil wash tower for treatment in the clay-treaters. First, by heat exchange with hot product from the treaters, and then by superheating in a gas-fired furnace, the feed is preheated to about 800°F and is passed through a bed of silica-alumina catalyst. This isomerises the hydrocarbons, imparting a higher octane rating to the petrol portion, as well as removing harmful acids and other oxygenates accompanying the oil. The heavy oil is essentially unaffected by this oil-treating operation.

Small amounts of carbon are deposited in the catalyst during the process cycle and, therefore, two reactors are employed, one being regenerated by burning off the carbon deposit with nitrogen containing a small amount of air, while the other is used for the treating process.

The reactor effluent is heat-exchanged with the feed to the reactors and then cooled and condensed. This condensed product is mixed with the high-boiling hydrocarbon product from the bottom of the decanted oil flash tower and separates into liquid and gas phases in a product-separator drum. Water produced in the treating reactions is condensed out in this drum and drawn off to sewer. The gaseous product from the separator drum, referred to as "cracked gas", is compressed and added to the product from the gas wash tower, which is fed to an absorber tower for recovery of the valuable hydrocarbons. Lean oil is fed to the top of this bubble-cap column at a temperature of 100°F and a pressure of 220 psig and, in descending, absorbs from the ascending gas the valuable hydrocarbons. The absorber tail gas consists primarily of N_2, H_2, CO, CO_2 and the lower hydrocarbons. A portion of this is purged to the factory fuel-gas system in order to prevent a build-up of the nitrogen which enters the plant, both in the coal gas and as an impurity in the oxygen. The remainder of the gas, referred to as "external recycle" gas, is compressed and passed to the partial combustion section (see *British Chemical Engineering*, May, page 244) for re-forming of the hydrocarbons. During the volume shrinkage accompanying the gas absorption, some of the water vapour which saturates the gas feed to the absorber condenses out and is withdrawn from the fourth tray of the absorber, through a trap, to drain.

Rich oil from the base of the absorber is preheated by heat exchange with hot, lean oil to 450°F and is fed into a characteristically bottle-shaped, lean-oil still. Bottoms circulation through a gas-fired reboiler keeps the bottom temperature at about 560°F, which is sufficient to strip the hydrocarbons from the lean oil. A small purge of lean oil is maintained to the fractionator. This is balanced by a small make-up of lean oil from the lean oil stripper. The stripped lean oil heat-exchanges with rich oil and is then cooled by cooling water to the required temperature of 100°F before returning to the absorber tower.

Overheads from the lean-oil still are partially condensed, to provide reflux only, by a condenser-cooler with a heat load of about 35,000,000 Btu/hr. The uncondensed product gas is compressed to 240 psig and, after mixing with liquid products from the oil treaters, is cooled to 100°F. This

combined product passes to a separator drum, the vapours from which return to the absorber tower. The liquid from this separator is compressed to 290 psig and heated in a steam heater to 270°F before being fed through one of three feed points to a debutaniser tower. Reboiler heat is supplied to this tower by a thermo-siphon type of reboiler which maintains a bottom temperature of 420°F.

The tower top temperature is kept at 160°F by reflux control. The overheads from this tower, consisting mainly of C_3 and C_4 hydrocarbons are condensed into a reflux drum. A portion of the tower overheads is non-condensible at the operating conditions, and the tower pressure is maintained by throttling gas vapours with the reflux-drum pressure controller. This gas is returned to the absorber tower. Net liquid product is fed to the cat.-poly. feed surge-drum, where they are mixed with the C_3, C_4 fraction from the Arge product-recovery sections. The Kellogg C_3, C_4 product consists of approximately 70% olefins and 30% paraffins. The combined C_3, C_4 product provides feed for the cat.-poly. section. Bottoms from the debutaniser tower together with partially stabilised polymer petrol from the cat.-poly. section and the lean-oil purge make up the fractionator feed. This material is preheated to a suitable flash temperature in a gas-fired feed heater. To avoid superheated vapour conditions out of this heater, it is necessary to add to the tower feed-stream a quantity of the heavy-oil product from the tower bottoms as recycle oil. This material will assure liquid-vapour composition out of the furnace at the proper operating temperature.

The vapour-liquid feed then enters the tower flash-zone and the liquid dropping out to the stripping section of the tower is stripped with live steam to yield the heavy oil-bottoms product. This may either be thermally cracked or used as a fuel oil. The overhead product from the fractionator is a 430°F end-point petroleum containing essentially all the polymer product from the cat.-poly. section which was contained in the feed. The tower is operated so as to produce this product having a Reid vapour pressure of 7 psia. This vapour pressure is controlled by the quantity of butanes left in the polymer gasoline.

Two side-draw-off products are produced from the fractionator. The lightest of these is the lean-oil stripper feed, which may either be drawn from the seal-pot of the fourth or sixth tray from the top depending upon the composition desired. The vapour from this stripping tower where light-ends are stripped with steam goes back below the second tray from the top of the fractionator. The other side-stream product is the diesel-oil stripper feed which is withdrawn from the seal-pot of the eleventh tray from the top of the tower. Vapour return from this stripped tower enters below the ninth tray of the fractionator. The lean oil is pumped to the absorber and the diesel oil to storage. The stripping steam condenses out with the petrol and is drawn off to drain. The petrol, which is of an exceptionally high quality, is pumped from the reflux drum to storage.

(*b*) *Catalytic-Polymerisation Section.* Catalytic polymerisation of olefinic hydrocarbon gases to produce high-grade petrol is a standard operation in modern oil refineries and several modifications of the process exist. The plant in operation at Sasol (see Fig. 2) uses the system of the Polymer Corporation, namely, copper pyrophosphate catalyst admixed with charcoal supported in beds with provision for spraying cold quench oil in between each bed.

There are four polymerisation reactors operating in pairs. Each reactor, which is 4 ft in diameter and 25 ft high, has five beds of catalyst and charcoal mixture. Fresh feed for the cat.-poly. reactors has an olefin content of 60-70%. The feed stream is split into two portions. The larger is compressed to 900-1000 psi and heated first by exchange with reactor effluent and then by 500 psig superheated steam to a temperature of about 425°F, and then introduced into the top of the first of either pair or both pairs of reactors. The smaller portion of the split feed stream is mixed with recycle from the overhead of the cat.-poly. depropaniser tower, which contains a smaller proportion of unsaturated components and is used as a quench for the reaction. As the polymerisation reaction is highly exothermic, it is necessary to control the temperature. To this end, the cold quench oil is compressed to 1000 psig

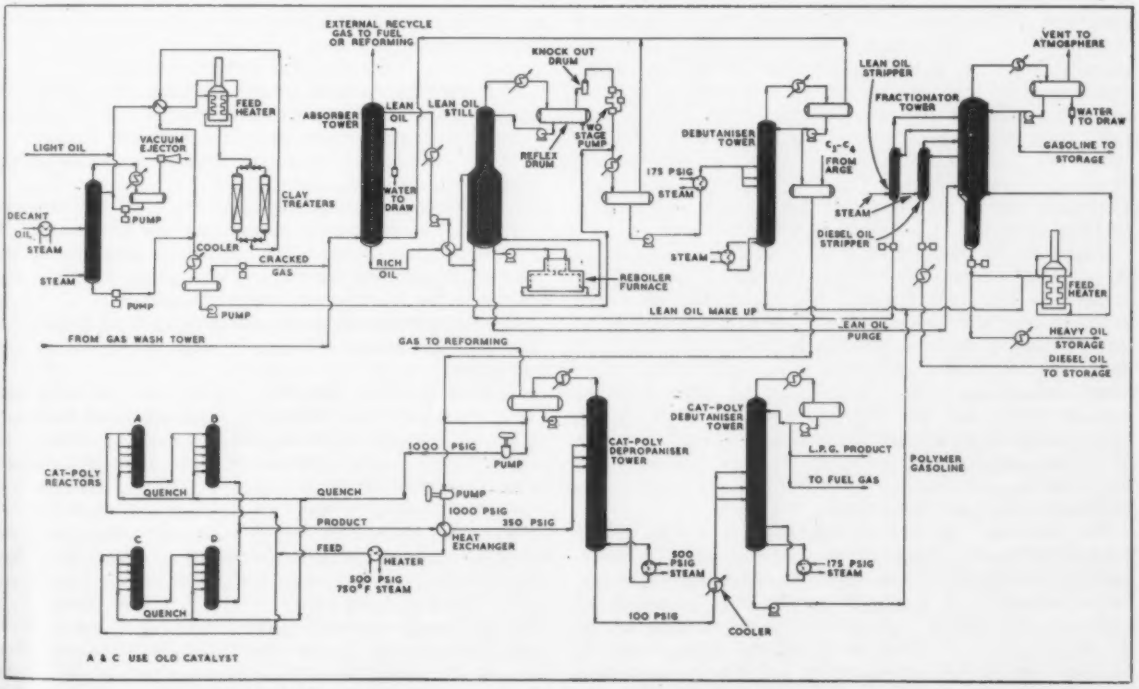


Fig. 2. Hydrocarbon recovery and cat.-poly. plants—Kellogg division.

and introduced to the appropriate points of the reactors.

Each pair of reactors operates in series, and, if one reactor has a charge of fresh catalyst and the other a charge of used catalyst, the feed meets the used catalyst first, so that the reaction in the fresh catalysts will not be too violent. The effluent from the second reactor is heat-exchanged with the incoming feed, and, after a reduction in pressure to 350 psig, is fed as a vapour-liquid mixture to one of three feed plates of a 30-plate depropaniser tower. This 72-ft column is provided with a thermo-siphon type of reboiler which is heated by superheated 500 psig steam maintaining a bottom temperature of 420°F. Overheads from this column are condensed at 100°F and 340 psig. A portion of these are used as reflux, another portion as quench oil and the remainder is recycled to the cat.-poly. feed drum. The non-condensible portion of the depropaniser overheads, consisting mainly of CO_2, methane and ethane, are added to the external recycle gas stream to the gas re-forming unit.

Bottoms from the depropaniser tower are cooled to 300°F, reduced to 100 psig pressure and introduced on to one of three feed plates of a 24-plate, 50-ft bubble-cap cat.-poly. debutaniser tower. A thermo-siphon type of reboiler, heated by 175 psig steam, maintains a bottom temperature of 300°F. This tower is designed to remove butanes from the depropanised polymer before it is sent to the fractionator tower in the hydrocarbon recovery section. Whatever butanes are required for the final gasoline are provided with the polymer gasoline from the base of this tower.

The tower overhead system operates with a flooded reflux condenser and drum with the reflux pump providing both tower reflux and overhead product flow. The product may be bottled as liquefied petroleum gas, recycled to the cat.-poly., feed drum or used as fuel-gas.

(*c*) *Chemicals Recovery Section*. The chemicals recovery section is provided to recover oxygenated chemicals from the aqueous solutions of alcohols, acids, aldehydes and ketones which are produced in the Kellogg and Arge synthesis units. Chemicals from both sections, in the form of an approximately 6% by weight aqueous solution, are combined and pass to a feed surge drum from which feed to the recovery unit is taken. Recycle chemical slop, i.e., off-specification products, is returned to the feed surge drum prior to reprocessing. Fresh feed contains a small amount of dissolved gases. When the pressure is reduced from the operating pressure in the synthesis units to atmosphere pressure in the surge drum, essentially all the gases flash away from the liquid and are vented to atmosphere. To ensure that air will not enter the drum at any time, a continuous stream of inert gas is fed to the drum.

Feed from the surge drum is introduced, half-way up, to the 40-plate, 6-ft diameter, primary distillation column. On account of the acids present, this tower, like the surge drum, is lined with stainless steel. The heat for boil-up of the overhead product and reflux is provided by injecting open steam through a distributor in the base of the tower. Steam condensate leaves the base of the tower together with the water and acid. To prevent any acid from distilling overhead, an alkali solution is injected into the tower on to two trays near the tower top. The acid bottoms from the tower is also treated with alkali prior to disposal by biological action or other means.

The overhead vapours from the tower are condensed and used as reflux and as feed to the carbonyl stripped tower. Feed to this tower contains alcohols, esters, aldehydes and ketones in addition to approximately 25% by weight of water. In this column—all columns in this section are of the bubble-cap type—feed is introduced through one of three alternative feed points, depending on the concentration of carbonyls in the feed. Carbonyls include aldehydes, ketones and esters. Heat is supplied in a steam-tube reboiler in the base of the tower. The bottoms product from the carbonyl stripper tower contains the alcohols together with a certain amount of water which must be removed before the alcohols can be further purified. The overhead product stream is further treated in the solvent recovery section.

Dehydration of the aqueous alcohols is effected, in the usual manner, through their heterogeneous benzene, azeotrope. The feed is introduced to the alcohol dehydrator where, in the presence of benzene, the water is distilled overhead. After condensation, the overheads separate into two layers in the separator drum. The benzene-rich phase is returned to the alcohol dehydrator tower and the water-rich layer is stripped, by open steam, of benzene and alcohol in the benzene stripper-tower where water is rejected from the system as a bottom product. Anhydrous alcohols are produced from the bottom of the alcohol deyhdrator tower and passed to the hydrogenator for further refining.

Hydrogenation Process

The hydrogenation operation is included to eliminate traces of carbonyls and gum-forming components from the crude, dehydrated alcohols. The alcohol feed is pumped to a pressure of about 500 psi, injected into a circulating stream of hydrogen and heated, first by exchange with product gases and then, in a steam heater, to about 300°F. This vapourised mixture is then passed down through the hydrogenator, where the resulting catalytic reaction converts the residual aldehydes and ketones to alcohols. The hydrogenated stream is heat-exchanged with incoming feed and is then cooled to about 100°F, when the alcohols condense and separate from the hydrogen. These alcohols are fed at atmospheric pressure to the alcohol fractionator tower. This tower is operated in two ways: (*a*) ethanol is produced as an overheads product and the heavier alcohols removed as a bottom product for treatment in the solvent recovery section; and (*b*) ethanol-propanol, the so-called motor alcohol for blending with petrol, is produced as an overheads product, and butanol and heavier alcohols from the bottoms are further treated in the solvent recovery section.

(*d*) *Solvent Recovery*. This system consists of:

(1) Three distillation towers designed to separate the major components of the overheads stream from the carbonyl stripper of the chemicals recovery section.

(2) Two product alcohol towers for refining of the separated alcohols.

(3) An aldehyde hydrogenator. As aldehydes are not produced in sufficient quantity and the local market is not such as to warrant refining of the aldehydes, these are hydrogenated to the corresponding alcohols and returned to the chemicals recovery section.

All distillation columns in this section are of bubble-cap type with dimensions dictated by ease of separation and throughput.

(1) Feed from the carbonyl stripper reflux drum is sent to the aldehyde tower, where the light aldehydes, acetaldehyde and propion-aldehyde are separated overhead. In order to increase the volatility of these aldehydes relative to acetone, the nearest boiling component of the bottoms product, the tower is operated as an extractive distillation column with the solvent liquid, water, introduced near the top of the column. The ketones, mainly acetone and methyl-ethyl ketone (M.E.K.), and the alcohols remain in solution in the water and are removed as a bottoms stream. It is necessary to operate with a high ratio of water-to-chemical feed to accomplish the separation. To allow the condensation of the aldehydes with cooling water at 80°F, the tower operates under a slight positve pressure in the reflux

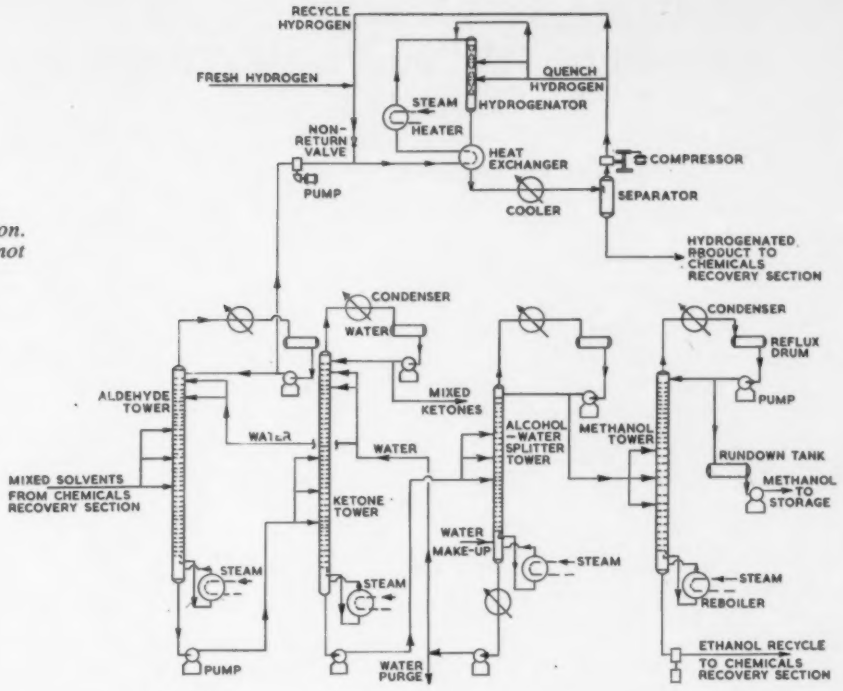


Fig. 3. Solvent recovery section. The heavy alcohols tower is not shown.

drum. The mixture of aldehydes, with a small amount of ketones, is hydrogenated and converted to alcohols.

The aqueous stream of the aldehyde-tower bottoms which contains, in addition to the above-mentioned components, a small amount of butylaldehyde, is fed to the ketone tower. In this tower a split is effected between M.E.K., the higher boiling ketone, and the light alcohol, methanol. As in the aldehyde tower, a stream of solvent water is employed to increase the relative volatility. A molar percentage of water of at least 80% is required on the trays to effect the desired separation. The ketones, acetone and M.E.K., plus about 12% of water and small amounts of butylaldehyde and heavy ketones are separated overhead as the distillate stream and further purified in a batch still which will be described in the fourth of this series of articles. The dilute aqueous solution of alcohols is removed from the bottom of this tower and pumped to the alcohol-water splitter tower.

This feed stream contains over 95% water, the other components being primarily methanol and ethanol. In this tower the separation is made between the alcohols and water by distillation at atmospheric pressure. The alcohols pass up the tower and are removed as the overhead product. The bottoms stream from this column is essentially pure water and is cooled to 125°F and pumped back to the aldehyde and ketone towers, where it is used as the solvent. A small purge and make-up is maintained. Overheads from the column are primarily methanol and ethanol, with a small ketone impurity and about 15% water.

(2) *Product Alcohol Towers.* This 85% alcohol solution is pumped to the methanol tower for final separation. The lighter-boiling methanol is fractionated overhead and the higher-boiling ethanol and water are separated to the bottoms. This column operates under atmospheric pressure in the reflux drum. The overhead product, containing 91% w/w methanol, is transferred to storage. The bottoms stream, containing some 80% w/w ethanol, is recycled to the chemicals recovery section.

Bottoms from the alcohol fractionator in the chemicals recovery section, containing either propanol, butanol and a small amount of ethanol, or butanol and heavier alcohols contaminated with some propanol, is fed to the heavy alcohols splitter. With the first mixture, the propanol, containing about 1.5% w/w of ethanol and 2% w/w butanol is distilled overhead and, after cooling, pumped to storage. The butanol, containing some heavier alcohols, is pumped to intermediate storage. This bottoms product is either sold as crude alcohols or redistilled in a bath still to yield pure butanol, pure pentanol and heavy alcohols, which are used as frothing agents in metallurgical flotation processes. With the second mixture, the butanol containing the small amount of contaminant propanol and about 1% w/w pentanol, forms the overhead product and is cooled and pumped to storage.

(3) *Aldehyde Hydrogenator.* The overhead products from the aldehyde tower, containing a mixture of acetaldehyde and propionaldehyde plus a small amount of acetone, are pumped by a high-pressure reciprocating pump to about 550 psig and injected into a circulating stream of hydrogen. The hydrogen-chemicals mixture passes through a feed-product heat exchanger, where it is heated to about 200°F, to a feed preheater where heat is supplied by 175 psig steam. The exit temperature is about 300°F. A portion of the hydrogen can by-pass the heaters to act as a reaction quench. The feed enters the top of the hydrogenator which contains three beds of nickel catalyst. During their passage down through these catalyst beds, the aldehydes (and acetone) are converted to the corresponding alcohols with evolution of heat. The quench is introduced above each catalyst bed for temperature control.

Products from the hydrogenator are heat-exchanged and then cooled to about 100°F. At this temperature the alcohols separate from the hydrogen in a separator and are drawn off for recycle to the chemicals recovery section. The excess hydrogen is withdrawn and is recirculated. A small purge is maintained to keep the hydrogen purity at the desired level.

SCALING UP OF PLANT AND PROCESSES

Abstracts of selected papers read during the first half of a joint symposium held in London recently by the Institution of Chemical Engineers, the Society of Chemical Industry, Het Koninklijk Instituut van Ingenieurs, and De Koninklijke Nederlandse Chemische Vereninging are published below

SCALING UP OF REACTORS FROM A KNOWLEDGE OF KINETICS

by Prof. K. G. Denbigh

BEFORE SCALING UP, it is necessary to decide whether to conduct the process batchwise or continuously. In the latter case one has the choice of either a tubular reactor or a set of continuously stirred reactors (C.S.T.R.). The aim will be to find the process giving the best yield.

Batch and Tubular Reactors. Residence times are influenced greatly by the type of reactor. In a tubular reactor they will vary, especially if the flow is laminar, although under turbulent flow the distribution will not be large. In the latter case "plug flow" is a good approximation, and in its chemical kinetics the tubular reactor is closely akin to the batch process, whose duration is equal to the time of passage of the plug.

Continuously Stirred Reactor (C.S.T.R.). In a well-agitated C.S.T.R. the outflow composition and vessel contents composition are identical but lower than the average in a batch or tubular reactor handling the same system. For the case of two reagents, reacting in a tubular or batch reactor, for a given conversion, a certain value of their final concentration is demanded. The C.S.T.R. for the same conversion and feed conditions must operate all the time under this same concentration. Hence the average reaction rate will be slower for the C.S.T.R. than for the batch or tubular one. As a result, the volume of the C.S.T.R. must be much greater than for the batch or tubular reaction, a difficulty surmounted by conducting the continuous process in two or more stages. Further, the yield of the desired product (apart from conversion) may be greater or less than in a batch or tubular reactor.

Kinetic Factors Affecting Yield. For a reaction typified by

$$RH + HNO_3 = RNO_2 + H_2O$$

water will dilute the acid, so that the instantaneous yield (yield from each infinitesimal quantity of RH nitrated) varies during nitration. It may either fall with acid dilution or reach a maximum at a particular concentration at which the instantaneous yield will be a maximum.

In the first case the batch or tubular reactor gives a higher average yield because the average acid strength is higher. The best that can be done with the C.S.T.R. is to use a larger excess of nitrating acid (maybe uneconomic), to increase the number of tanks in sequence, or to divide the feed between the tanks. For the second case, the C.T.S.R. may, if correctly designed, give the higher yield.

Effect of Order of Reaction. First, the case of two competing reactions of different orders may be considered

$$2A + B = X \text{ (desired product)}$$
$$A + B = Y \text{ (undesired product)}$$

where the former is a second-order reaction and the latter a first-order reaction. The rate of production of X with respect to Y is given by

$$\frac{dx}{dy} = \frac{k_1 a}{k_2}$$

where k_1 and k_2 are the rate constants and a is the momentary concentration of A. Therefore, if the useful reaction is of a higher order than the wasteful one, then it is an advantage to raise the concentration of the reagent; conversely, if the wasteful reaction has the higher order, then lowering the concentration will enhance the yield, but it will also lower the rate so that a larger vessel is required. In the first case the tubular or batch reactor is preferred. In the latter case the C.S.T.R. is preferable.

A useful equation can be derived expressing overall yield in terms of time and initial and final concentrations of reagent

$$\Phi = 1 - \frac{r}{b} + \frac{r}{a_0}(k_2 t + \ln r/b) \qquad \ldots.(10)$$

where $r = k_2/2k_1$ and $b = (a_0 + r)\ \exp\ k_2 r - a_0$.

Degradation Reactions. Here the following types of reaction are considered

$$\left.\begin{aligned} A + B &\longrightarrow X \\ X + B &\longrightarrow Y \end{aligned}\right\} \qquad \ldots.(1)$$

and

$$\left.\begin{aligned} A + B &\rightleftharpoons X \\ &\longrightarrow Y \end{aligned}\right\} \qquad \ldots.(2)$$

where the X-forming reaction is reversible and the Y-forming reaction is slow by comparison. In both cases the concentration of X passes through a maximum after a time t_m, which, in the reaction system, should be achieved for the highest yield. The batchwise process is the better here, since the required residence time can be easily kept.

For the reaction system (1) assuming the X and Y forming reactions are directly proportional to A and X respectively, then for a batch process

$$\Phi_m = \exp\left(\frac{r}{1-r} \cdot \ln r\right)$$

for a C.S.T.R.

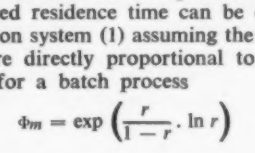
$$\Phi_m = (1 + r + 2r^{\frac{1}{2}})^{-1}$$

$$r = \frac{k_2}{k_1}$$

The yield in each is greatest when the ratio of velocity constants is unity (which is probably near the truth for many reactions involving successive substitution), but for the batch process the yield is 47% higher than the C.T.S.R.

The Effect of Temperature. The yield of a complex reaction may often be improved by making a continuous change of temperature during the course of the reaction and here the tubular may score.

The following reaction system



illustrates this concept. If the temperature coefficient of reaction 1 is less than that of reaction 2 and that of 3 exceeds that of 4, it will be advantageous to use a low temperature for the X accumulating reaction followed by a higher temperature for the X conversion reaction. Reversible exothermic reactions also have an optimum temperature profile.

Design of Reactor. This requires, in the first place, a capacity determination which will depend upon the kinetics. For a batch reaction the standard differential equations will need integration (graphically if temperature is not constant) and in the tubular reaction deviations from true plug flow will require allowance to be made. For the C.S.T.R. the basic equations are algebraic and are iterative when more than one tank is used.

Discussion

Replying to discussions and questions, PROF. DENBIGH stated that in the large stirred tank reactor a high standard of mixing was not difficult to obtain, provided the viscosity was not too high. It was necessary, however, for the stirrer to revolve a large number of times during the half-life of the chemical reaction. This was not difficult to achieve in large mixers, especially since their *raison d'être* was a slow chemical reaction. In the case of continuous tubular reactors operating under viscous flow conditions, the performance would fall short of the plug flow performance by something like 20-30%. He thought that several months' study of kinetics of reactions at laboratory scale would pay handsome dividends when it came to the full-scale design or in operating existing processes.

ECONOMIC ASPECTS

by R. G. Dickerson

TO ILLUSTRATE the nature and extent of the economies possible in complete plants, an example is given in which the construction cost and unit operating costs of a plant are estimated and compared for three different outputs. The sizing of equipment and the basic information has been provided by the Process Development Division of the Research and Development Department of The Distillers Co. Ltd., and the example illustrates a range of problems typical of many catalytic vapour-phase processes.

To present as complete a picture as possible of the economics of the proposals, preliminary estimates of construction and production costs were prepared for plants of 500, 3500 and 14,000 tons per annum capacity, which will be referred to as plants A, B and C respectively.

Using the comparison formula:

$$P_2 = P_1 \ (X_2/X_1)^x$$

Where P_1 = price of the first "unit"; P_2 = price of the second "unit"; X_1 = capacity of the first "unit"; and X_2 = capacity of the second "unit"

it may be seen [from figures supplied in the paper] that the relationship between plant B, which is seven times as large as plant A, is indicated by the exponent of 0.63, and between C and B (four times larger) by the exponent 0.77, or an overall exponent of 0.7. To enable an appreciation of the reasons for these results to be formed, some comments on the design considerations of the individual components are given below.

In nearly all cases, there are two sets of pumps with motors and starters for all applications in plants A and B, and three sets for plant C. This gives greater flexibility for the largest plant, although it would have been possible to have only two sets of still larger size with consequent capital saving.

Although the increase required between plants A and B has been achieved by retaining the same numbers of tanks and vessels and increasing their dimensions, the size of some of the most costly vessels in plant B approaches the practical limit, and therefore the required total capacity for plant C involves an increased number of units.

The increase in capacity of columns from plant A to plant B has been effected by increased dimensions of the same numbers of columns. In the step from plant B to plant C, however, a limit is reached in the liquid loading on these columns which makes it increasingly difficult, as the diameter is increased, to obtain sufficient length of overflow weir and to achieve a satisfactorily low hydraulic gradient on the bubble-cap plates. It was therefore necessary to duplicate some of the columns rather than increase their dimensions.

It was possible to consider using a very small, reasonably-priced, high-speed turbine-driven centrifugal compressor for item No. 1 in plant A, and in view of the key nature of this unit a standby set is also included. For plants B and C the range of the type of machine selected for plant A did not extend far enough to meet requirements without multiplication of units. There was, therefore, a change in the design of these units which accounts for a rather larger increase than would be expected in the capital cost between plants A and B. For plants B and C, there are two machines in each case, each capable of taking half load.

It was decided to install one gas cooler per reactor, and the increased capacity of reactors was obtained by multiplication of units. In another case the limit in size of a particular proprietary type of heat exchanger was reached with plant B, and therefore, in total, in the step between plants B and C, the cost was largely affected by multiplication of units.

The effect of scaling up on labour required is most marked. With the 500 tons per annum plant it was considered that three men each shift were necessary, but, with a modern, well-instrumented plant, this would rise to four for the 3500 tons per annum plant and six for the 14,000 tons per annum plant.

In most chemical plants when scaling up from a small or medium-size plant to a large plant, the effect of multiplication of units is often considerable. Assuming there is some split-up available of the actual or estimated cost of the plant which is to be used as the basis for the scaling-up (or down) estimate, then it is well worth the time taken to go over the process, comparing technical data with costs for individual groups of items and forming a quick assessment whether each group can be increased in output by increased dimensions or by multiplication of units. The probable cost of each group can then be assessed by using a suitable exponent in the formula (or an average of 0.6), or by simple multiplication. The total arrived at in this way is probably the best short-cut method that can be applied in a short time. Unfortunately, published information on this subject is extremely rare in this country. However, if time and basic information are not available when scaling up the cost of a small commercial plant to one considerably larger, an exponent of about 0.72 will provide relative costs with a fair degree of accuracy.

Discussion

In reply to questions, the author said that the figure of 5% for maintenance was stated to be an arbitrary one, and in practice, the figure varies considerably from plant to plant and during the life of a particular plant. Some of the engineering costs given in the paper included site erection and these figures in practice again vary considerably. Overall, however, the bulk factors given in the paper were good enough for a "quick shot", for that is their purpose.

Asked to say something about the application of the six-tenths or two-thirds rule to the scaling of costs on plants containing a great deal of solids-handling equipment, he said he could not give a direct example, especially as the costs of conveyor equipment increased by sudden jumps due to a range of models having the same type and size of drive.

INFLUENCE OF DESIGN IN ROTATING DISC CONTACTORS

by Dr. G. H. Reman

IN USING relations between dimensional groups to describe the influence of structural factors upon the capacity and efficiency of a rotating disc contactor (r.d.c.) the properties of the liquids are neglected. The size of droplets of the dispersed phase is controlled in each compartment by the rotor speed, and flat rotor discs and stator rings are employed. The flow pattern produced is a torodial one. Since an r.d.c. deals with an agitated emulsion, a relationship describing droplet size is needed. For this purpose the group

$$\frac{N^3 R^5}{HD^2}$$

can be used.

There is then the problem of finding an expression to deal with the complex flow pattern and the flooding and settling tendencies. The current method to deal with these effects is to correct the observed capacities by dividing them by the ratio of the minimum to free cross-section of the shell. For ratios of dispersed-to-continuous phase flow rates greater than 3, the operation of the contactor becomes unstable; hence the design should be based on a lower ratio than 3.

Data for contactors ranging from 2 to 16 in. show that the following factors increase efficiency: increase in rotor speed, specific load, and increase in flow rate of dispersed phase with respect to the continuous phase. Efficiency decreases rapidly with increase in stator internal diameter, and it is also reduced by compartment height. The shell diameter has little influence upon efficiency.

Compartment efficiency, provided no entrainment occurs, can be described by the formula

$$\frac{\eta}{H} \simeq \frac{6k}{d} \cdot \frac{hD}{vD} \cdot E^{0.5} \text{ for } \eta \leqslant 0.3 \qquad \ldots.(3)$$

The limitation to 0.3 or less is quite realistic. On account of undesirable mixing effects, attempts to improve compartment efficiency by increasing rotor speed are not generally successful.

The main variables for correlation of efficiency data are n/H and $N^3 R^5/HD^2$ if mixing in the extraction zone can be neglected. The mass transfer coefficient, k, may be assumed also to be determined by the energy input.

Increase in flow rate of the dispersed phase results in increased efficiency because hindered settling of the drops increases the hold-up of the dispersed phase. The column diameter effect upon efficiency is believed to be practically negligible.

In general, the scaling-up efficiency can be found from the formula $n/H \simeq D^{-0.15}$ for energy inputs lower than those given by $N^3R^5/HD^2 = 0.1$. With higher energy inputs than this, the effect of mixing cannot be disregarded and efficiency decreases more rapidly with column diameter and no rules can be given.

Discussion

Objections were raised to the use of dimensional groups, but DR. REMAN pointed out that, for example, basing the capacity of the r.d.c. at 65% of the flooding point velocities had, in practice, proved satisfactory. The assumption that drop size and mass-transfer coefficient are proportional to power input was likewise justifiable, although there was a divergence of opinion on the dependence of mass-transfer coefficient upon power input.

So far, he said, the largest size of r.d.c. constructed using the rules he had described was 3½ m., but this has not yet been put into operation. However, 2½-m. columns had been operated successfully by means of them. The explanation for the decrease in efficiency with increased rotor speed was that the height of a mass-transfer stage approached the order of magnitude of a mixing-stage height as the speed of the rotor was increased. The droplet sizes obtained with systems used in rotary disc contactors were between 1 and 2 mm. in diameter.

PROBLEMS ENCOUNTERED IN STIRRED SLURRY REACTORS

by Dr. Ir. J. G. van der Vusse

WITH SLURRY-AGITATING systems the relationships between stirrer variables and rate-determining factors from which scaling-up rules are derived have usually to be found from small-scale work. A rule is required in the first place for scaling-up conditions wherein all the solid particles are maintained in suspension. Other factors dictating the standard of mixing are heat- and mass-transfer rates, the prevention of clogging of filters in reactors employing solid catalysts and the suppression of any undesirable side reactions. In many cases, for example, it would be necessary for a reactant to be diluted immediately it enters a reactor. In this case, the scaling-up rule must provide for immediate mixing.

In the absence of scaling-up rules derived from process analysis and small-scale work, a common practice is to keep one of the following constant: the Reynolds number ($\rho nL^2/\mu$), the Froude number (n^2L/g), power consumption per unit volume and peripheral speed. Where experiments are carried out on a regular model, geometrical similarity will exist on scaling up. The practice is to keep one of the following terms constant where n is the stirrer speed and L the scale ratio: nL^2, n^2L, n^3L^2 for turbulent conditions and n for the viscous region and finally nL. These rules should be applied with a knowledge of the determining process factors.

Two cases have to be considered depending upon whether the stirrer creates an isotropic or non-isotropic field.

In isotropic turbulence the concept of eddy diffusion can be applied to both liquid and solid phases. The equation

$$\frac{\phi e^{\phi}}{e^{\phi}-1} \leqslant \frac{Z}{Z_1} \qquad \ldots.(4)$$

can be derived from the diffusion equation for most practical cases. $\phi > 1$ in Equation (4) becomes

$$\phi \leqslant \frac{Z}{Z_1} \text{ or } E > vZ_1 \qquad \ldots.(5)$$

This means that all particles are just maintained in suspension if the eddy diffusion coefficient is just equal to the product of particle velocity, and the height of the particles without stirring. The rules for scaling up can be derived from Equation (5) and the fact that eddy diffusivity is proportional to the product of scale and the intensity of turbulence. In the turbulent region the group nL^2/vZ_1 must be kept constant for scaling up.

If the particle velocity v remains the same, and if the bed height is proportional to the scale, then the impeller tip speed must be kept the same.

In the viscous region, nL^2/vZ_1 will provide a margin of safety in scaling up.

In mixers employing one or a few stirrers, non-isotropic conditions exist and the eddy diffusivity concept can no longer be applied. The power to maintain particles in suspension in the turbulent region can be given by

$$P = C_1 (W_d W_c)^{0.5} v \frac{\Delta\rho}{(\rho_d \rho_c)^{0.5}} \qquad \ldots.(6)$$

where C_1 depends upon the type of stirrer used.

For scaling up, P can usefully be expressed in terms of

stirrer variables. In the case of baffled vessels where $P \propto \rho_c n^3 L^5$, the rule for geometric scaling-up is that n^3L^5 is kept constant. In the viscous region the rule of equal power input per unit of liquid volume leads to safe design.

Mass- and Heat-transfer Rates

The mass- and heat-transfer rates for conditions where all the particles are part suspended is given by the following expressions

Mass transfer:

$$\frac{K}{(2g\nu)^{1/3}} = 9 \times 10^{-2} \left(\frac{D}{\nu}\right)^{0.5} \left(\frac{\Delta\rho}{\rho_c}\right)^{\frac{1}{2}}$$

Heat transfer:

$$\frac{h}{C_p\rho(2g\nu)^{\frac{1}{2}}} = 11.5 \times 10^{-2} \left(\frac{k}{\mu C_p}\right)^{0.5} \left(\frac{\Delta\rho}{\rho_c}\right)^{\frac{1}{2}}$$

These expressions are independent of the vessel dimensions.

To prevent filter clogging it is necessary to maintain the ratio of peripheral stirrer speed to filtration velocity above a certain critical value which is found experimentally.

Both on the small scale and the larger scale residence times have to be maintained equal, which requires equal mixing times and degrees of turbulence. The mixing times will be identical if the number of revolutions of the stirrer is kept the same on both scales.

Symbols Used

C_p = specific heat at constant pressure (J. kg.$^{-1}$ (°C)$^{-1}$);
E = eddy diffusion coefficient (m.^{2} sec.$^{-1}$);
g = acceleration of gravity (m. sec.$^{-2}$);
h = heat-transfer rate (J. sec.$^{-1}$ m.$^{-2}$ (°C)$^{-1}$);
k = thermal conductivity (J. sec.$^{-1}$ m.$^{-1}$ (°C)$^{-1}$);
K = mass-transfer rate (m. sec.$^{-1}$);
l = length (m.);
L = length of stirrer (m.);
M = mass (kg. mol.);
n = number of revolutions of stirrer (sec.$^{-1}$);
P = power consumption (W.);
v = velocity (m. sec.$^{-1}$);
V = volume (m.^{3});
W = weight (N.);
z = vertical co-ordinate (m.);
Z = height, depth (m.);
μ = dynamic viscosity (kg. m.$^{-1}$ sec.$^{-1}$);
ν = kinematic viscosity (m^2 sec.$^{-1}$);
ρ = density (kg. m.$^{-3}$); and
ϕ = dimensionless quantity $\left(\frac{vZ}{E}\right)$

Subscripts

c = continuous phase; and
d = dispersed phase.

MODEL TESTS WITH CYCLONES

by A. L. De Gelder

THIS PAPER gives data for the design of cyclones, and their comparison is derived from model tests. The separating action of a cyclone is the result of the opposition of two forces, the centrifugal and the axial forces, and the separating effect depends upon their ratio. The particles reaching the wall of the cyclone are carried to the apex through a boundary layer at the wall. The separation between particles leaving with the exit fluid stream and those collected is assumed in the subsequent treatment to take place over a cylindrical surface of diameter equal to the overflow diameter. The size of the smallest particle that can be collected will depend upon physical factors such as the density ratio, viscosity, etc., and upon the geometric design of the cyclone. The important factors in the design are pressure drop and separating performance and, in comparing a model with a larger counterpart, the following dimensionless groups have to be considered:

(*a*) flow factor—a function of Reynolds number;
(*b*) centrifugal force coefficient—related to the Froude number; and
(*c*) a coefficient measuring the separating effect.

The Design of a Cyclone. Model laws do not help directly, but they can provide useful data for further calculations. Using Taylor's calculation for the thickness of the boundary layer, they allow a good approximation to the pressure loss according to the relation.

$$p_o - p_2 = (\alpha^{-2} - 1) \cdot \tfrac{1}{2}\rho V_o^2 + \tfrac{1}{2}\rho V_2^2 \qquad \ldots.(1)$$

where α is given by the expression

$$\frac{\alpha_\infty}{1 - \frac{1}{6} G \frac{F_1}{F_o} \sqrt{\left(\frac{2}{Re \sin \gamma}\right)}}. \qquad \ldots.(2)$$

A critical Reynolds number, which depends upon the cyclone dimensions defined by

$$Re_{cr} = \frac{G^2}{18 \sin \gamma} \left(\frac{F_1}{F_o}\right)^2$$

must be exceeded several fold if the cyclone is to perform satisfactorily. The physical significance of this number is that it corresponds to conditions in the cyclone where all the fluid comes from the boundary layer and is not, therefore, subjected to the separating influence of a vortex.

With a model cyclone, agreement between actual and calculated pressure drop results using (1), and the flow formula (2) is excellent except that for Re values below $5,6 \times Re_{cr}$ there is a divergence probably due to wall effect.

The separating performance can be measured by the diameter of the largest particle that cannot be retained. An approximate value of this diameter may be found from the formula

$$d_o = D_2\left[0.349\, Re\, \frac{(D_1 - D_2)}{b_o}\left(\frac{p^1}{p} - 1\right)\right]^{-\frac{1}{2}} \qquad \ldots.(3)$$

which contains no experimental values. Equation (3) assumes that the particles do not hinder each other and that kinematic viscosity is unaffected by the concentration of solids in the fluid. In practice, therefore, the pressure loss will be less than the theoretical. Nevertheless, this equation in conjunction with (1), (2) and (3) is useful for predicting the performance of cyclones.

In an appendix a method for calculating the flow factor from Equation (2) is shown.

Symbols Used

b_0 = width of feed aperture;
D_1 = cyclone diameter;
D_2 = diameter of overflow aperture;
F_0 = area of feed aperture;
$F_1 = \frac{1}{4}\pi D_1^2$
F_2 = area of overflow aperture;
Q = capacity = V_0/F_0;
V_0 = inlet velocity, $V_2 = Q/F_2$;
z = flow factor;
γ = half apex angle; and
ν = kinematic viscosity.

Discussion

One contributor wanted to know whether the procedures described could be extended to hydraulic cyclones. The method of calculation proposed by C. J. Stainnard some years ago gave results in close agreement with those calculated by Mr. Gelder's method, both being in close agreement with practice for pressure loss determinations.

MR. GELDER, in reply, said that he thought the agreement accidental so far as Mr. Stainnard's method was concerned, because, according to this method, pressure drop should increase with viscosity. This is contrary to experience.

An objection was raised to the use of the term critical for the Reynolds number limitation. The author pointed out that the term was used to denote a condition which had to be fulfilled if the cyclone were to work properly.

(*Photo: Scotsman Photos*)

THE DOUNREAY FAST REACTOR

An immense steel sphere, the largest pressure vessel ever constructed, now dominating the rugged scenery by the shores of the Pentland Firth, at Dounreay, is a striking monument to the foresight of those who initiated its construction and contents

THE pressure vessel at Dounreay houses the principal components of the pilot liquid-metal-cooled fast reactor power plant, costing between £15 million and £20 million. One of the main purposes for the building of this power reactor is to investigate the possibility of generating more fuel from a reactor than is fed to it. Successful breeding would mean increasing the supply of fissionable material based on uranium by a factor of 140.

Apart from the aims of putting the breeding process on a commercial scale, the fast reactor is to be investigated as a source of power for industry. The real difficulties with this kind of reactor centre on the large temperature gradients and thermal stresses occuring in the fuel elements themselves. The heat flux is around 3×10^5 Btu per hour per sq. ft. Other studies for which the reactor will be used include engineering, irradiation and the safety problems which arise in the operation of a reactor of this type. In addition, new chemical processing methods for the treatment of used fuel elements are to be tested and developed, and the fabrication of fuel elements employing such radioactive materials as plutonium or uranium-233 will also be examined.

Reactor Construction

The reactor proper consists essentially of a core containing the neutron source, which in the early stages will be highly enriched uranium. The core is surrounded by a blanket of breeding material which may be thorium-232 or uranium-238. To maintain effective use of neutrons a reflector is provided.

As such reactors generate heat after they shut down, the heat-transfer system must provide cooling independently of the forced convection system employed during normal operation.

The reactor core consists of an arrangement of fuel rods fitted into metal containers of niobium. This is a novel use for niobium, a metal which has shown excellent resistance to hot sodium-potassium and uranium. The fuel rods are packed closely together in the form of a regular hexagon of a width and height of 21 in. The breeding blanket consists of about 2000 natural uranium rods arranged vertically, each rod being 8 ft in length by 1¼ in. in diameter. In addition, two lengths of natural uranium are situated at either end of the core. The assembly is contained in a stainless-steel reactor vessel, 10 ft 6 in. in diameter and 20 ft high. The core and breeder are cooled by a sodium-potassium alloy which is fed to the top of the reactor and flows downwards to the base, passing *en route* between the finned fuel elements and the blanket elements, and through the inner tubes of the former.

There are twelve separate cooling units, each provided with a pair of electromagnetic pumps. Each cooling unit is made up of two circuits, a primary circuit for cooling the reactor and a secondary one for removing heat from the reactor primary-circuit fluid and for transferring it to the steam-generating plant. The purpose of the two-stage system is to contain the radioactivity in one circuit and to prevent it appearing outside the reactor. The blanket elements are contained in sheaths of stainless steel.

The neutron generation in the reactor is controlled by moving groups of fuel elements in or out of the core. The elements are formed into groups, of which a dozen,

situated at the perimeter of the core, constitute the control rods. These are raised or lowered by a transmission system employing a magnetic clutch, an arrangement which permits the prime mover to be fixed outside the vessel and avoids the need to have a shaft passing through the vessel and the attendant problem of providing a gland or seal. The control rods are held in position by an electromagnet; failure of electrical power will cause the control rods to drop out of the core and shut down the reactor. Should the control-rod mechanism fail, two rods of neutron-absorbing boron may be lowered into a position close to the core by an independent mechanism.

The conception of the reactor as an experimental tool has been carefully planned for in its mechanical design. It is therefore possible to substitute easily components of different design; in fact, the entire assembly within the reactor permits wide variation of detail.

Heat Exchanger Circuits

Fig. 5 shows the essentials of the dual circuit and its main components. Sodium-potassium alloy, preferred to sodium alone since it remains liquid at room temperature, is a novelty in engineering practice and its use in inaccessible spaces as in this reactor is a completely new application. Ordinary centrifugal pumps could not be considered for use in the circuits, since they embody glands which would inevitably leak. Furthermore, flow measurement cannot be tackled by conventional methods. Consequently, the circuits employ glandless electromagnetic pumps and flow meters which are virtually electromagnetic pumps working in reverse. The primary circuits are heavily shielded and the tanks of the pumps are increased in depth to accommodate a heavy radiation shielding plug.

The valves employed in the circuits have to resist the action of the alkali metals and, like the pumps, they must be leak-proof and cannot employ ordinary glands; they are, therefore, fitted with bellows seals. The body and seatings are constructed from stainless steel and the plugs have a stellited surface. The pipe-work consists of lengths of butt-welded stainless-steel tubing and great care has been taken to ensure that the internal welding bead is as smooth as possible.

The accumulation of oxygen in the system is something which has to be carefully avoided, for the oxides of sodium are extremely corrosive to the components of the circuit. The components therefore carry a subsidiary circuit which cools a fraction of the main throughput of the pumps. The decrease in temperature depresses the solubility of the alkali-metal oxides so that they can be readily separated from the molten metals. The traps in the system are air-cooled by forced convection.

Chemical Separation Processes

Although little information is at present available on the separation processes to be carried out at the site, the main picture is fairly clear. The spent fuel elements will come from the fast reactor embedded in lead and contained in a stainless-steel coffin. These elements will contain uranium, plutonium and fission products. The containers will be removed from the irradiated metal mechanically by remote control. The kind of equipment to be used for this purpose will include remotely-operated lathes and milling machines submerged in water. The fuel elements will be dissolved in nitric acid and the various materials separated from the solution by a four-cycle solvent extraction process. The pure uranium solution will be transferred to the metal fabricating plant for the preparation of uranium. The plutonium fraction will be sent to the Windscale works and the fission products to the evaporation and storage sections of the plant which will be concerned with the problem of effluent disposal.

The solution of rod material, after its acidity has been adjusted and the sludge separated from it, will be extracted with tri-butyl-phosphate. The procedure will remove the fissile material from the acid solution and is to be carried out in a pulsed mixer-settler extraction unit. The raffinate containing the remaining fission products, among which are cæsium-137 and strontium-90, will be sent to the evaporation plant. As this liquor will contain long-lived highly radioactive products, it cannot be discharged to the sea. The liquor, therefore, will be treated by the most convenient method of reducing storage space, evaporation, and the concentrate is to be stored in stainless-steel tanks. In the evaporation plant traces of tri-butyl-phosphate, or other phosphates which may be employed in the extraction process, will be removed by

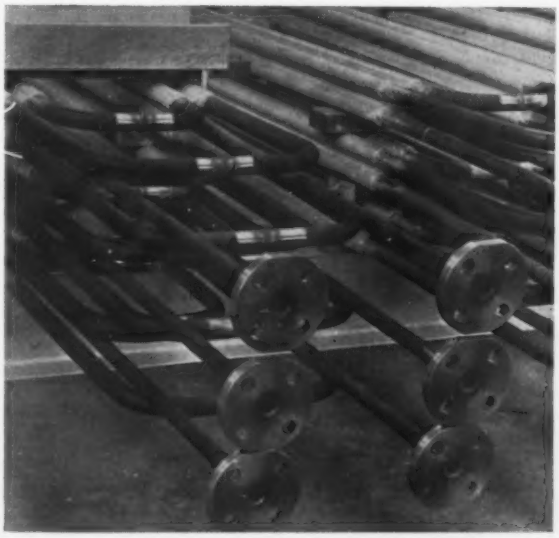


Fig. 1 (left). Close-up of the elements in the secondary heat exchangers for the Dounreay boiler plant. Fig. 2. Assembling primary liquid-metal/liquid-metal heat exchanger pipe-work in stainless steel for the fast reactor vessel.

(Photos: John Thompson Ltd)

stream stripping before evaporation. The condensate from this process is harmless, so it can be transferred to the sea.

Pumps and valves are not to be used in this part of the plant, since their maintenance would be a highly hazardous affair. Vacuum-lift methods will, therefore, be employed for liquid transference, and steam-jet ejectors will be used for this purpose. These will be situated outside the biological shield and have traps of ample capacity fitted between them and the vessels to be evacuated. At parts of the plant where a liquid flow has to be divided, distributors will be used.

Outstanding among other plant at Dounreay is the materials-testing reactor. This will be used to investigate, among other problems, the effect of radiation on the physical and mechanical properties, corrosion resistance and high-temperature dimensional stability of many materials. Part of the reactor will be set aside for investigating the effects of irradiation on the corrosion properties of various reactor coolants. A further field of study will be the behaviour of graphite under irradiation, of great importance in thermal reactor design. The mechanical and physical properties of container materials, such as alloys of the rarer metals, beryllium, zirconium, niobium, molybdenum and magnesium, etc., will also be investigated, as well as the various types of steel used in pressure shells and for supporting structures.

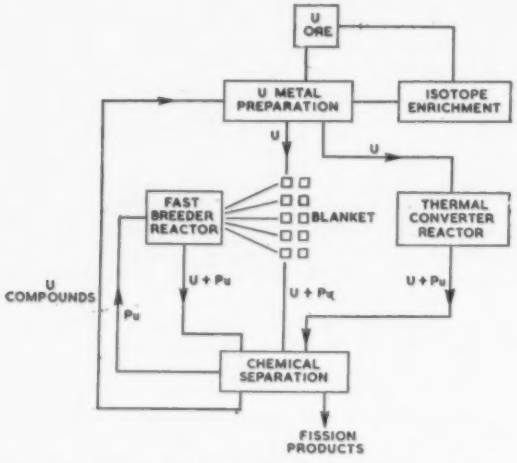


Fig. 3. System for breeding fissile material from uranium.

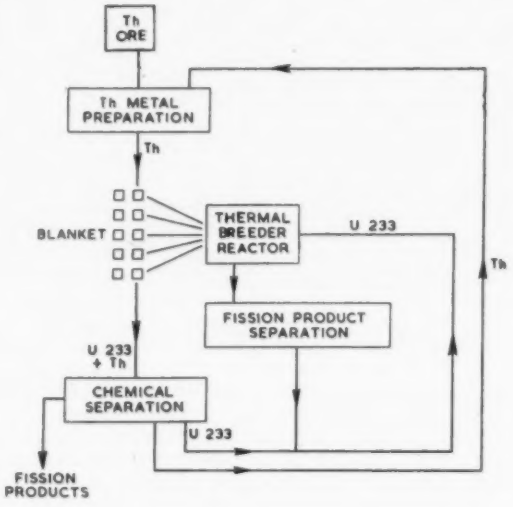


Fig. 4 (right). Fuel cycle for breeding nuclear fuel from thorium.

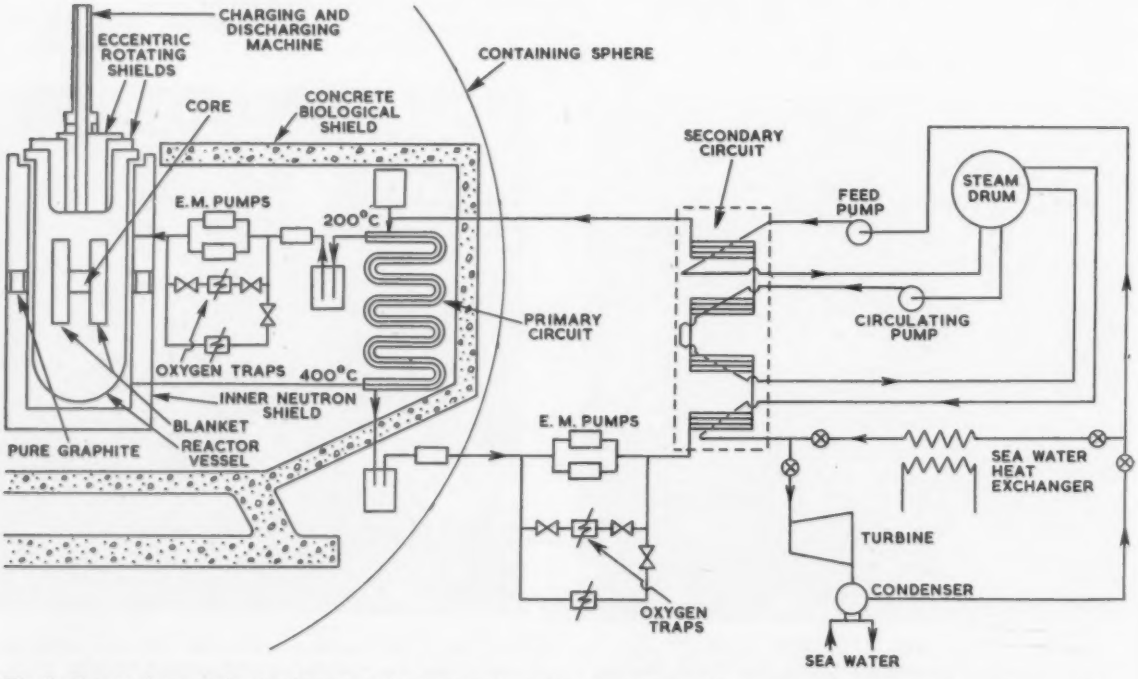


Fig. 5. Circuits for transferring heat from fast reactor to power plant. Two of these can operate under natural convection.

TRAINING CHEMICAL ENGINEERS

The concluding part, below, of the report on the recent symposium on chemical engineering education (see also pp. 316-317, June issue), deals with papers on new educational trends

New Trends in Teaching

The Place of Mathematics

by E. S. Sellers

THE TRAINING of chemical engineers must hinge around its main aim of design and must recognise the mental processes demanded by this aim. The latter requires analysis, synthesis or both, and the blind use of empirical methods must be eschewed. In dealing with a problem, as complete an analysis as possible must be made and it is here that mathematics has its principal role. There has been divergence of opinion in the profession about the use of mathematics, and the present level was rather low. One reason was that past teaching dealt with the subject in terms of standardised procedures, and did not teach the student genuine powers of analysis.

Some problems can only be tackled by the use of mathematics, and verbal statements have to be replaced by mathematical ones. The main trouble which besets the student is not so much the manipulation of symbols but this act of description by symbols. The derivation of insoluble equations is another difficulty, and here the problem may have to be remoulded in an idealised form which renders it amenable to solution if only as an approximation to reality. The success of this operation depends upon the judgment of the person working on the problem and will require a great deal of practice.

Mathematics is a difficult subject to learn. It must be taught in a manner which helps the student to distinguish physical from mathematical arguments and must develop in harmony with the rest of the course; when one mathematical method is learned it should be applied in another part of the course. This method of teaching would prove to the student the usefulness of mathematics.

Courses have been devised at Swansea according to these principles. In the first year, school algebra is revised and instruction given in simple linear differential equations. Various problems are then used, e.g., batch distillation to illustrate the mathematics and to give the student the opportunity to solve simple differential equations. In the second year, the student, after revising the previous year's work, tackles problems in the fields of fluid mechanics, heat transfer and so on, and here he has resort to harder differential equations, partial differential equations, Bessel functions, etc. The third year sees the introduction of the calculus of finite differences and numerical solutions. The subject is illustrated in its entirety by examples.

The Place of Thermodynamics

by K. G. Denbigh

THE MAIN argument for the inclusion of thermodynamics in the syllabus is its vocational use. The first law, the basis for the familiar energy balance, is not limited to systems in equilibrium. It underlies the basis of Bernoulli's widely-used equation in fluid mechanics. The second law, however, is generally confined to systems at equilibrium. By means of the second law, one can determine the effect of changes of temperature, pressure and composition on many of the important chemical engineering operations.

The third law, in its simplest form, asserts that the entropy change in any isothermal process involving substances in internal equilibrium approaches zero at absolute zero. The use of this law makes possible determination of the standard free energies of formation of substances by purely calorimetric methods. Finally, there is the principle of microscopic reversibility, which gives information on systems in which there are coupled transport processes. Thermodynamics can help the student to make a proper choice of independent variables in a manufacturing process, and this experience will prove of value to him in tackling variable problems for an industrial process, even though the latter may be concerned more with rates than with equilibria.

Clear distinction must be made between rates and equilibria. In ammonia synthesis, for example, the process approaches fairly closely to equilibrium and thermodynamics is therefore useful. With ammonia oxidation, on the other hand, the yield is determined by the relative speeds of two forward processes which compete with each other. The nitric-oxide-producing reaction is about 19 times as fast as the nitrogen-producing reaction, thereby giving a yield of 95% of nitric oxide.

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$
$$4NH_3 + 3O_2 = 2N_2 + 6H_2O$$

In the case of ammonia synthesis, thermodynamics is useful for fixing the most economic operating pressure. In ammonia oxidation, on the other hand, one of the main problems is to choose a catalyst which will give the highest rate of the desired reaction and, in particular, to avoid too long a contact time, since it is the product of the second reaction, nitrogen, which is the stable end-product at equilibrium.

A thorough understanding of the first and second laws is necessary, but extensive use of perfect gases for explaining the theory is a mistake unless it is followed by proofs of relations which apply to all states of aggregation; for example, that relating the change of latent heat with temperature. A danger is that the teacher with his eye to applications may tend to neglect the theory. This will restrict the initiative of the student. There is no need for the student to commit anything but three or four basic equations to memory. From these, the whole range of thermodynamics equations can be derived.

The Function and Place of Practical Training

by F. Rumford

A PILOT-PLANT laboratory is essential in teaching, and the question arises: How should practical work be set out? The main thing is for the engineer to have an inquiring mind about equipment, and he should know what effects variation in conditions will produce.

The traditional plant laboratory provided with filter presses, evaporators, distillation columns and so on, should never be used for experiments such as standard heat balances or filtration tests which have been performed dozens of times by other students in the past. Any system of experimental exercises must present an intellectual challenge and be more than a test of a capacity for hard work. In the field of evaporation, for example, one can do a heat balance and overall heat-transfer determination or one can investigate the influence of surface tension upon overall heat-transfer coefficient in evaporators. The latter is by far the more useful, but its practice does contain a danger of specialisation in three or four unit operations.

In sizeable classes this may not be serious, since experts in differing fields will be able to interchange experience freely.

In the experimental project system, a first step is to get a group of students to commission a new piece of plant. This sometimes means damage to equipment, but it is better for a student to make his blunders as an undergraduate than to make them in industry. A further step is to provide actual industrial plant experience. Casual vacation work at plants usually gives the student experience of routine operation only and gives him little opportunity to use his mental powers. At Glasgow, a fortnight of the spring term is allocated for special investigations at works. In this scheme a number of teams are distributed over a number of works. Each team, on arrival at its destination, then gets down to the job of tackling an engineering problem. A further two weeks is then spent at college in preparing a full report upon the problems and their solution, upon which the firms concerned are invited to comment.

In addition to this exercise, which all students must carry out, there is a continuous works practice school where undergraduates spend about six weeks and, at present, there are two such establishments. As a result, the university has been able to investigate four types of water-cooling tower, industrial crystallisation in three different plants, dust precipitation, solvent recovery in a drying plant and benzol removal from coke-oven gas and a range of problems associated with the manufacture and concentration of nitric and sulphuric acids. One of the difficulties in operating such a practice school is finance.

The Changing Nature of the Unit Operation Concept

by J. M. Coulson

ONLY DURING the past twenty years have serious courses in chemical engineering been started. There had been no appreciable undergraduate courses before 1945. Previously, most training had been of one year, taken postgraduately by students who were generally chemists.

The first change in the approach to problems that had occurred in the last two decades was the consideration of a number of unit operations, which are now looked upon as examples of either mass, momentum and heat transfer. Another major change has been to consider fluid mechanics and kinetics in the design of equipment. Other important developments in outlook have taken place in the study of dynamic characteristics of plants in order to select the most satisfactory automatic control systems for them; in the development of new unit operations such as extractive distillation; and in the improved understanding of plant and the evolution of new types of plant for well-recognised operations. Work that has been carried out on the subject of diffusion, including alternative theories to the widely used two-film theory, has not led to any significant improvement in designs. Hypersorption and freeze-drying and the gas-separation process of the atomic energy field for isotope separation are among newly developing unit operations.

With bubble-cap columns, designers nowadays pay careful attention to the fluid dynamics requirements, whereas some years ago the estimation of the number of theoretical stages was all that was done. Attention to fluid dynamics has brought forth useful flooding-correlations for packed columns and permitted designs to give optimum operating conditions. The Lurgi extractor, the Luna evaporator and Kittel and Turbogrid trays are among notable equipment advances.

During the past ten years there has emerged what may be called chemical engineering science, and this should not be mistaken for chemical engineering. Although of value, chemical engineering science has the danger of leading to indifference to urgency and of detaching the student from the mechanical engineer's attention to actual equipment. It would be a pity if the chemical engineer lost sight of the importance and difficulties of maintenance. The tutored vacations scheme had been very valuable in bringing home to chemical engineering students the realities of chemical plant life.

Schools' Science Training

by R. Groves

THE TEACHING of science is now firmly established in all schools, and our aim as teachers is to produce scientists who are cultured, well-educated men. Such men are needed in chemical engineering, where the qualities of leadership and adaptability are so essential. The two main difficulties in the schools are lack of laboratory space and the shortage of good science teachers. The former is being greatly helped by the Industrial Scientific Fund, but the latter is the abiding problem which must be tackled; some suggestions about this problem are included.

A technologist must have scientific training of a high standard, coupled with practical ability. He must have individuality, adaptability, be willing to take responsibility and indeed thrive on it. He must, above all, be able to get on with his fellows and be able to work in a team, for co-operative effort is the very life-blood of technology. Moreover, as he is going to be a most important person in the future community he must have a real sense of service to it. That is my interpretation of what our aim is, for surely leadership and character are going to be needed more than ever in the modern industrial world with all its complex labour problems and difficulties. I think that those qualities I have mentioned are there in abundance in the best of our grammar and public schools' sixth forms. The science specialist at school devotes a quarter to a third of his time-table to subjects outside his science. Now this can be real education. First and foremost must come learning to write good English; a foreign language and current affairs should also be included. Indeed, it is just to these particular boys who are specialising in science that the ablest teachers on the arts side must be directed, for boys who get really keen on science are apt to ask what is the use of all the other subjects they do. It is therefore essential to have a man to teach them English who has a real love for his subject, who can fire his pupils and, so to speak, appeal to the poet in all of them, giving them a love and an appreciation for good writing.

Discussion

PROF. P. V. DANKWERTS stressed the necessity of teaching the application of mathematics and thermodynamics all the time, and thought the generalised solution should arise from a particular case of the problem. It was necessary to face the danger of over-academicism in the universities and get more people from industry into the universities.

Efforts in this direction, in Holland, were described by DR. A. KLINKENBERG. Men from industry, such as technical managers, and directors of research can become special professors in Dutch universities, where they can spend one or two days during the week. Reference to a similar idea contained in Dr. Bowden's recent booklet on the future of Manchester College of Technology was made by PROF. F. MORTON, who stated that the College intended to go ahead with the plan.

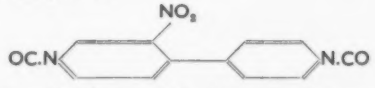
IN HIS summing-up of the symposium, PROF. NEWITT made a plea for a complete revision of the chemical engineering curriculum, divorced from the idea of its being part chemistry and part mechanical engineering. He thought that more fundamental physics should be included and outdated material should be dropped from the course.

A USEFUL POLYESTER RUBBER

Vulkollan N, a German-made polyester rubber of potentially wide usefulness was described by Dr. H. Gudgeon at a recent meeting of the Chemical Society, Hull. The following is an abstract of his remarks

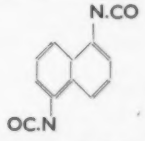
IN Britain during the Second World War a thermoplastic rubber, Vulcaprene A, was made by heating together hexamethylene di-isocyanate (HDI) and a polyester amide derived from ethylene glycol, ethanolamine and adipic acid. The product was resistant to oils and oxidation and almost impermeable to gases, but it was sensitive to hydrolysis and expensive. Although it was used in barrage balloons, interest in Vulcaprene as a rubber later diminished.

Meanwhile, developments in Germany were taking a different course. When polyethylene adipate was heated with HDI, products were obtained which crystallised rapidly and, therefore, were useless as rubbers. To prevent the crystallisation, Otto Bayer, an organic chemist of the classical school, of the Bayer company, chose to vary the isocyanate. Further, he had the bright idea of using the following compound:



to lengthen the chain, and then of using an alkaline-reducing agent to effect cross-linking through joining two

N atoms (N=N, NH-NH, or $-N=N-$). To his surprise, he found that he had an excellent rubber without carrying out the reduction step. Unlike the product obtained with HDI, this rubber did not freeze rapidly. Bayer guessed that it might be the bulkiness of the isocyanate residue that was interfering with the crystallisation he had observed when using HDI, and, after examining many other di-isocyanates with large molecules, he selected naphthylene-1:5-di-isocyanate as one of the best.



Naphthylene-1:5-di-isocynate.

On this simple view of lengthening the chain of a linear polyester by reaction with a di-isocyanate, one would expect to get a purely linear rubber. But, in fact, somewhat more than a molecular proportion of the di-isocyanate is used and the rubber obtained is very slightly cross-linked. We know that, because it only swells, and does not dissolve, in organic solvents. This is, in fact, the consequence of a side-reaction. The polyester used always contains a little water—or water can be absorbed from the atmosphere. This water reacts with the isocyanate ends of the polymer chains to form urea groups, which, in turn, can react with other isocyanate ends to introduce branches, and ultimately cross-link.

The rubber which Bayer obtained from polyethylene adipate and NDI he called Vulkollan N. It had remarkable properties—in particular, tensile strength and tear-strength higher than those of any other rubber, and a resistance to abrasion some 5 to 10 times better than that of the best of other rubbers. It became possible to contemplate tyres that might outlast cars.

Structure in Relation to Properties

Why has Vulkollan these outstanding properties? The chemical structure of the rubber fulfils all the general requirements of rubbery polymers. Vulkollan is made up of long flexible chains, with low, attractive forces between them and occasional cross-links. But, in addition, it has some peculiarities which distinguish it from other rubbers.

In particular, it is made up of chains of polyethylene adipate, which, when not hindered in some way, crystallise rapidly. In the unstretched state the disruption of structure due to the bulky isocyanate residues and the restraint exercised by the few cross-links is about enough to prevent the molecular segments from lining up into crystallites. But when the rubber is stretched the molecular chains are forcibly aligned and then they do form crystallites, which are oriented to some degree along the axis (as in polyester fibres). This explains the very high tensile strength of Vulkollan—when in the stretched state the rubber resembles a fibre, like linear polyesters.

With polyethylene adipate rubbers, crystallisation sets in at much smaller elongations than in other rubbers. At room temperature it commences quite rapidly at 50% elongation, although the amount of crystallisation at equilibrium is small. The extent of crystallisation rises with elongation, thus:

Extension, %	100	200	300	400
Crystalline content ...	3	21	33	38

Thirty-eight per cent is the highest observed crystalline content in any rubber, with the possible exception of isobutylene.

If a freshly stretched strip of Vulkollan is released, it snaps back at once to its original dimensions. But if a strip is stretched to three times its length for an hour, and then released, it only partly recovers. The polyester segments have crystallised in the extended state, and they persist in that state—emphasising even more the resemblance of the stretched rubber to a fibre. The crystallites can be broken up, i.e., can be "melted", by warming the rubber, which then recovers fully.

Tear Strength

The same phenomena account for the unusually high tear strength, which is a special case of tensile strength. In tests for tear strength the act of tearing is simulated by using a specimen which is notched to facilitate the initiation of the tear. When such a specimen is stretched, the forces are largely concentrated at the extremity of the notch; the local elongation is high. This results in a high degree of crystallisation at the notch. Propagation of the tear is resisted by the bunched crystallites, which may be regarded as a sort of micro-fibrous reinforcement of the notch. The crystallites have a stiffening effect which causes a rapid rise in tensile modulus, resulting in resistance to further strain.

Polyethylene adipate is the highest-melting polyester that gives useful rubbers. Storage polyesters, that melt above 50°C cannot be prevented from hardening by crystallisation. They would "set" so quickly, if they could, on stretching that they would be unlikely to recover on releasing the stress. Slightly lower-melting polyesters can be used, however, without serious sacrifice of strength. In fact, some crystalline polyesters melting somewhat below room temperatures give quite good rubbers. This is because the crystallisation temperature is dependent on elongation. Crystallisation occurs when

$$T \triangle S < \triangle H_p$$

T = temperature;
$\triangle S$ = entropy change;
$\triangle H_p$ = heat change

and since $\triangle H_p$ is constant, crystallisation occurs at a higher temperature the smaller $\triangle S$ becomes as a result of elongation.

The melting-point of polyethylene adipate rises quite sharply with elongation. It would not be surprising, therefore, to find that a crystalline polyester melting at about 0°C crystallised on stretching at room temperature. Polyethylene glutarate is such a compound. Its melting-point is 5°C, and it gives rubbers not much inferior to those from polyethylene adipate. It has an advantage, in that, because of its low melting-point, rubbers made from it are much less likely to harden through spontaneous crystallisation than those made from polyethylene adipate.

The influence of elongation on crystallisation is so strong that some polyesters which have never been induced to crystallise can be converted to rubbers which crystallise to some extent on stretching. Polypropylene adipate is an example, but the rubbers made from it are rather weak because the degree of crystallisation is small.

Another feature of the chemistry of Vulkollan may contribute something to its high strength—though this is at present pure speculation. Conventionally-cured rubbers contain loose ends of molecules, which can contribute little to strength. But Vulkollan is, we believe, virtually free from such loose ends, because an excess of isocyanate is used in making it, and free isocyanate groups at the ends of chains react with moisture to link the ends together. Exposure to atmospheric moisture is essential to complete the cure of Vulkollan.

It may be wondered why, if Vulkollan is such a wonderful rubber, so little has been heard of it—for it has been known for some 12 years. The answer is that the processes involved in its preparation are very difficult to control satisfactorily on a factory scale, and this has retarded its development. Considerable efforts are being made to overcome these difficulties, both in Europe and in the U.S.A., and there appear to be good prospects of a rubber of this type finding a place on the market during the next few years.

A STEEL WORKS RE-EQUIPPED

A TEN-YEAR programme of modernisation and re-equipment undertaken by the Workington Iron & Steel Co. and involving an expenditure of £6 million has now been virtually completed. Among the new plant that has been installed is a coke-oven battery (due to light-up in mid-June); a distillation column for handling pure coke-oven by-products; an additional sinter pan; and a wet washer for suppressing the emission of dust from sinter plant. Gas from the works coke-ovens is soon to be supplied through the local grid to an enlarged area extending from Wigton to Carlisle. Partly to be thoroughly prepared for this expansion, the company has invested £75,000 on installing the new coke-ovens. This equipment consists of 53 Woodall-Duckham Becker compound regenerative ovens and it will replace an equal number of ovens that have been in continuous service since 1936. A battery of 11 ovens installed in 1948 will continue to be used and the throughput of coal achieved by the 64 ovens will be maintained at 10,000 tons a week. The coke-ovens by-products plant, which employs a standard process and is of conventional design, recovers each week from the oven products 450 tons of tar (4.5% of the weight of the coal used), 120 tons of ammonium sulphate and 33,000 gallons of crude benzole. The benzole is refined to yield a variety of pure products, but at present the plant is engaged chiefly on the separation of nitration-grade toluene, benzene, xylene, etc. The tar is treated in the tar distillery of a neighbouring associated company.

The coke-oven gas after leaving the final scrubbers, is collected in a new 3-million-cu. ft holder from which it is distributed to the various consuming points. About 15 million cu. ft of the gas is produced daily, of which about 12 million are consumed in the works itself—for heating the coke-ovens, steam raising and metallurgical processes. The balance is supplied to the grid and to local industries. The four modern Stirling water-tube boilers with which the works' central boiler plant has been re-equipped are designed to use coke-oven gas, or blast-furnace gas—of which 140 milion cu. ft are produced per day. The gaseous boiler-fuel can be supplemented by liquid fuel, imported into the works.

The works' sintering plant consists now of a three-pan Greenawalt installation with a capacity of 900 tons of sinter a day. A second Traughber wet-gas-washer similar to the one recently installed is soon to be added to the plant.

Details of the coke-oven plant are as follows: The ovens are 41 ft long by 13 ft high with an average width of 16 in. tapering 2 in. from the coke side to the machine side, and they each hold about 14.5 tons of crushed coal. Every tenth oven is discharged in rotation, and an output of about 10 tons of coke every 16 or 17 minutes is obtained. The heating flues are maintained at a temperature of 1320°C. The new A.P.V. column in the refining plant gives a performance in excess of that indicated by laboratory trials.

AMERICAN LETTER

Engineering Registration in U.S.A.

IF the title of engineer is to be worth anything at all, it should imply a high degree of skill, but in many parts of the world the word is applied virtually without discrimination. In Britain, the popular view of an engineer is of a man who undertakes work of a direct mechanical nature, such as precision fitting and turning. However, it is also applied to highly-qualified specialists such as designers of bridges, chemical plants and power stations; everyone understands the distinction and few people seem to mind. In some other countries, no such easy-going, yet workable ambiguity is to be found. Sweden, for instance, protects the title "engineer" by law, and only those suitably trained and qualified at technical universities, or who hold equivalent status, can legally call themselves engineers. In parts of America, and elsewhere, the title may embrace such jobs as driving a train, operating a semi-automatic machine or even holding a bag of tools for a millwright.

However, during the last decade, moves to restrict the title to professional qualified people have become increasingly evident. This is not because of any public confusion, for, in general, "engineering" work refers to calculation and design, not to manufacture and construction. This desire for professional restriction is expressed by many engineers themselves, as well as by numerous employers, and there are many reasons behind this wish.

Undoubtedly, many engineers are concerned by the diminishing differential between salaried designers and hourly-paid construction men. This has created a desire for a professional pressure group on the lines of a medical association or a legal body, rather than for a trade-union type of organisation, which is considered by many to be unethical for professional men, even though quicker short-term benefits might be secured this way.

Accordingly, increasing emphasis and hopes are being placed on professional registration as a means of recognition and reward. This registration implies legal restriction of the title "Registered Professional Engineer" to those who are able to pass a written or an oral examination or both conducted by a State Board of Examiners and who also have sufficient practical experience in the field. At first, this may seem odd, since America is liberally furnished with State universities, endowed colleges and technical institutions of many kinds, and most of these grant degrees or other forms of recognition in specialised fields. Why, then, should a supreme qualification by a State Board be considered necessary?

One reason is because the standards of qualification vary so widely throughout the nation. No one will doubt that the requirements set by centres such as the Massachusetts' Institute of Technology or the Universities of Columbia or Michigan are of a very high order, yet there are other centres of learning where the teaching and qualifying standards are either so broad or so low as to be questionable. Nor do the professional institutions, as a rule, fulfil the role of higher examining and qualifying bodies on the lines of the senior British chartered institutions. This leads to a sort of Gresham's law of engineering, where, in the long run, the inferior lowers the general status of the good, rather than the other way round.

Most employers are concerned by this wide variation in educational standards as well as the lack of technical experience so frequently found in qualified men. Hence, a recently-admitted registered professional engineer can generally be relied upon to be sound in theory and practice and will usually be granted preference over a man of equal academic qualifications who has not obtained a registered professional licence. Indeed, for work such as land surveying, civil engineering and structural design, or any work involving dealing with public works, a professional licence is essential and the State Boards play a similar role to the chartered institutions in Britain, or the Board of Trade—one of the few Government examining and licensing bodies.

Because of the increasing emphasis on State registration, many U.S. engineers in categories not directly concerned with public works are taking steps to acquire professional licences, in the hope that they will be in an advantageous position, should either promotion or hard times ever come their way. Some of these categories include aeronautical, chemical, electrical, mechanical, metallurgical and mining engineering and the total number of registrations has risen sharply—from 10,000 in 1930 to 75,000 in 1945 and to about 200,000 at present.

The whole procedure of granting and obtaining a professional engineering licence is complicated, because each State has its own examinations and licensing board. Thus, even if an engineer is successful in obtaining a licence in one State, he is not automatically free to practise in other States. Should he have to work in another State, he must obtain a licence from the Board of Registration of that State. It is true that reciprocity between the State Boards generally allows a licence to be obtained without difficulty, on payment of about twenty-five dollars, and it is not uncommon when visiting a busy engineer's office in New York, say, to find the walls impressively festooned with a dozen or more licences from States in which the man has worked, or is likely to work.

Most Boards recognise four classes of engineer, which may be briefly defined thus:

Class 1. Graduate of an approved engineering course, plus four years of active practice, plus the successful passing of a written, or written and oral State Board Examination.

Class 2. Non-graduate, with ten or more years of experience in engineering work, plus the passing of a written, or written and oral State Board Examination.

Class 3. Graduate or non-graduate, who is at least 40 years of age and who can show a satisfactory record of fifteen years or more, as regards nature and responsibility.

Class 4. Applicant who holds a certificate of qualification issued from another State or the National Bureau of Engineering Registration.

Graduates who have passed the State Board Examination, but have not acquired the necessary four years of practical experience, and non-graduates who have six years or more of practical experience and have also passed Part I of the State Board Examination are known as engineers-in-training. This does not permit practice as a professional engineer, but indicates the intent of the recipient to qualify later for registration as a professional engineer.

BOILING POINTS OF STRONG CAUSTIC SODA SOLUTIONS

O. P. Kharbanda, D.Ch.E., A.M.I.Chem.E.

The only reliable data for boiling points of strong caustic soda solutions are those of Antropoff and Sommer.[1] Unfortunately, these data are only for atmospheric pressure and the concentration extends only to 98.7 wt. % Standiford and Badger[2] have recently extrapolated these data to a concentration of 99.8 wt. %, and a pressure down to 5 in. Hg. absolute. Their extrapolations, particularly with regard to pressure, are believed to be more reliable than the previous available figures.[3] The final results have been plotted[2] as boiling point against concentration with pressure as parameter. The interpolation on this graph is rather difficult, since the pressure lines are indicated only at intervals of 5 in. Hg. absolute and the relevant relationship is non-linear.

The accompanying nomogram reproduces their data almost exactly and, in addition, makes the interpolation easy. The pressures are indicated at intervals of 1 in. Hg. absolute. The use of the nomogram is simple and the answer is easily obtained by

means of a straight ruler. In the region of these high concentrations, it is preferable[2] to use the total weight % solids rather than the actual caustic content determined analytically.

Example: What is the boiling point, at a pressure of 15 in. Hg. absolute, of a caustic soda solution containing 99.5 wt. % solids? Connect 99.5% on concentration scale with 15 in. on the pressure scale by means of a straight ruler and read the temperature on the boiling-point scale. This is found to be 747°F. The actual figure from an enlarged graph of Reference 2 is 748°F.

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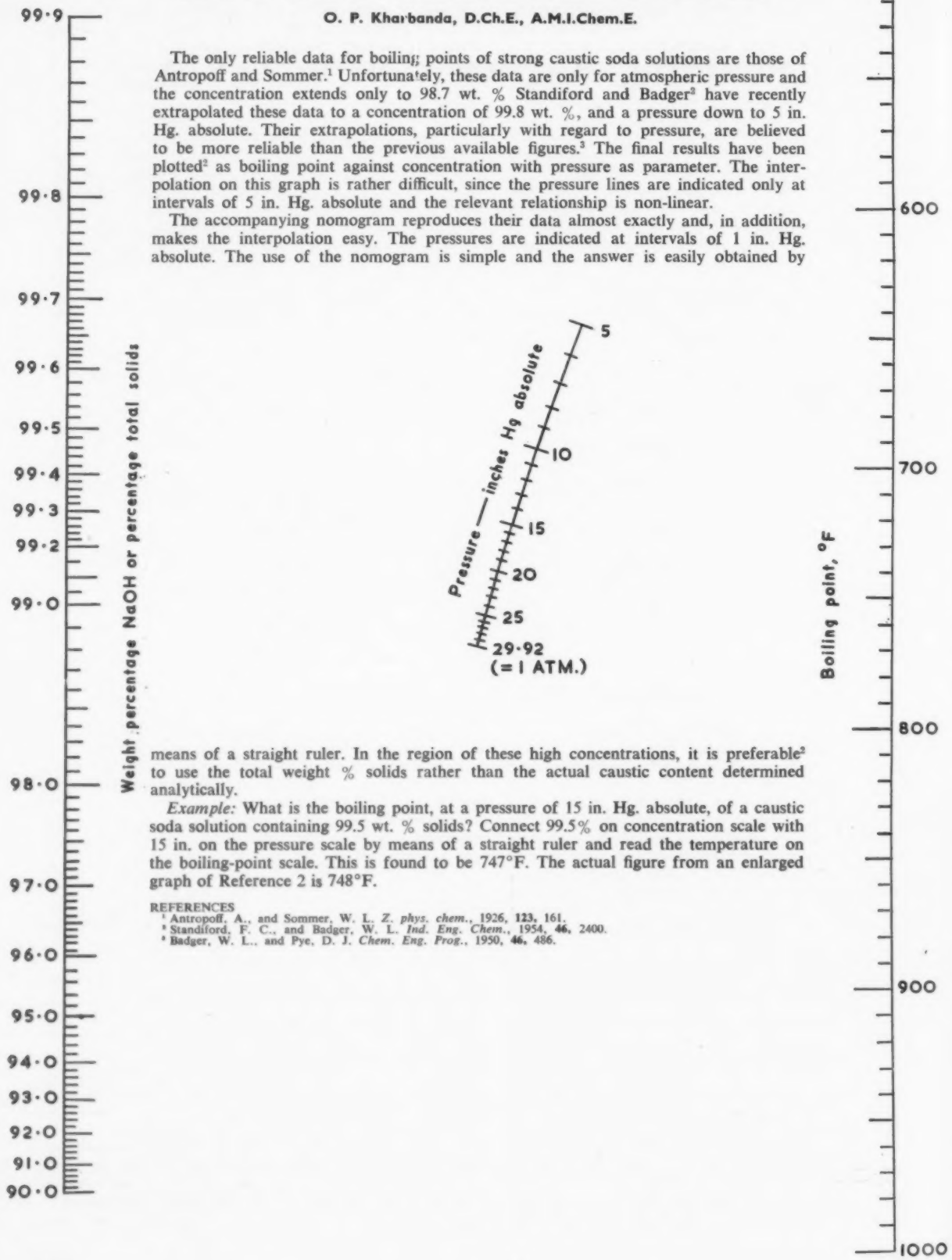
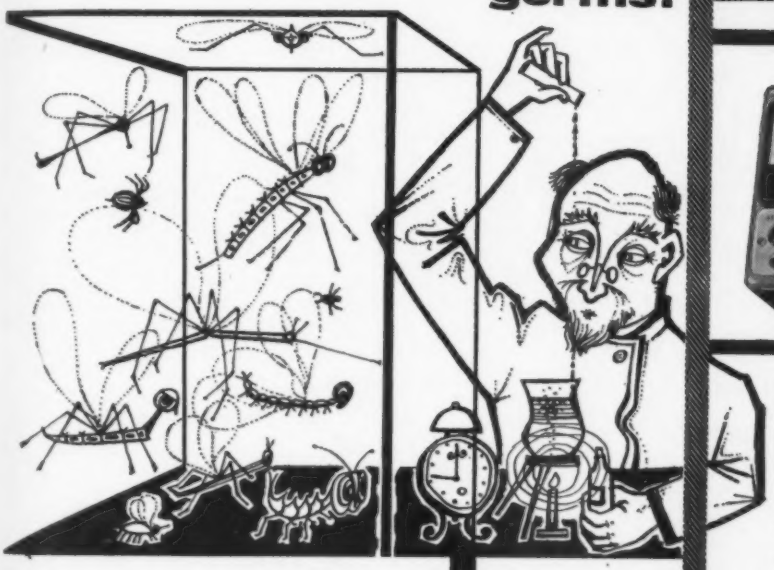
[2] Standiford, F. C., and Badger, W. L. *Ind. Eng. Chem.*, 1954, **46**, 2400.
[3] Badger, W. L., and Pye, D. J. *Chem. Eng. Prog.*, 1950, **46**, 486.



Louis Pasteur

had to work fasteur to avoid coming to terms with any of his germs!



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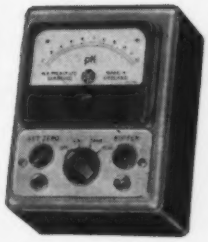

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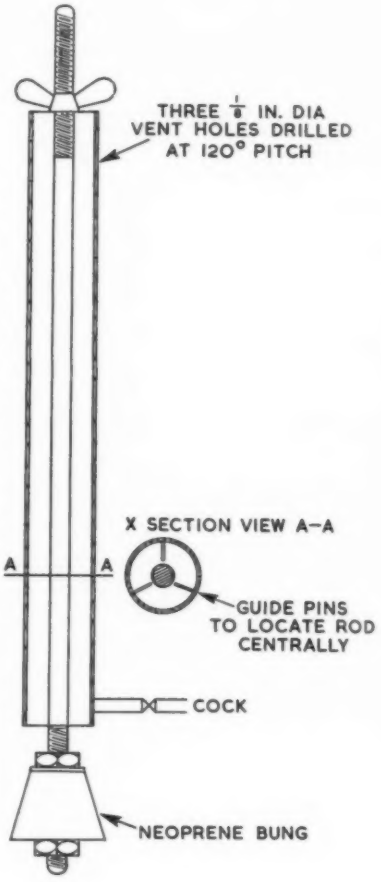
PROCESS ENGINEER'S NOTEBOOK

Dip-Can Sampling Device

THE IMPORTANCE of securing truly representative samples of liquids stored in tanks for laboratory testing is generally realised. The dip-can has wide application and consists of a weighted vessel fitted with a removable stopper. The can is lowered to the required depth, and the stopper then removed by pulling a cord attached to the stopper. This method of sampling is repeated at different levels in the tank and the various samples are blended to give the representative sample.

A simple device that has been used successfully for obtaining samples from tanks up to 15 ft in depth was fabricated from $\frac{3}{4}$-in. B.S.P. pipe through which passed a $\frac{1}{4}$-in. diameter rod. An adjustable wing-nut was fitted at one end of the rod, with a stoppered neoprene bung at the opposite end. Guide pins secured to the $\frac{3}{4}$-in. pipe and spaced at suitable intervals maintained the rod concentrically with the wall. In use, the wing-nut is released so as to free the bung from the opposite end, thus permitting the entry of the liquid to be sampled as the tube is lowered steadily into the tank. When the tube reaches the required depth (usually the bottom), the wing-nut is tightened, entrapping a column of liquid. The tube is raised and then secured by Terry clips fitted to a guard-rail or other suitable structure. The sample may then be run off via a cock mounted at the bottom of the tube. Obviously the volume of the annulus should be adjusted by an amount dependent on the volume of the sample required for testing. The one in question had a capacity of about 1 litre. The tube may also be calibrated to act as combined dip-rod and sampling device. P.E.B.

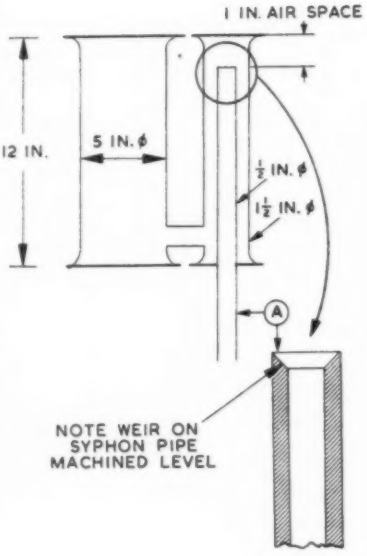


Syphon for Automatic Emptying of Vessels

THE SYPHON DEVICE described here has been successfully employed in small plants for the intermittent and automatic emptying of vessels.

The 12 × 5-in. diameter pot illustrated is charged to capacity. As soon as the level in the charge pot reaches the height of the weir on the syphon starter-tube A, the liquid flows uniformly over the weir, entraining the air from the air space above A. Once all the air has been ejected, the syphon is established and the vessel emptied. The sizes given are relative to the scale of automatic syphon used. For longer syphons with greater capacities, two or three syphon starter-tubes of different but relative sizes and at varying heights (somewhat on the lines of a series of organ pipes) would be required. An arrangement of this type with the smallest syphon starter in $\frac{1}{4}$-in. diameter bore lead pipe has been constructed and performed quite satisfactorily.

F. MOLYNEUX.



Fan First Aid

THE PERFORMANCE of a fume-extraction system was observed to deteriorate rapidly. Inspection revealed a number of perforations on the reaction side of the fan casing caused by corrosion. The fan rotor blades were also affected. The casing was repaired by applying to the affected parts several layers of fibre-glass treated with epoxy resin and a hardener. The tips of the fan blades were restored by the same technique, except that short strips of aluminium sheets were placed in front of the blades to add rigidity to the repaired sections.

These pieces were added after the first layer of fibre-glass had been applied. The remaining layers were then added. This repair held out long enough to keep the plant on production until the arrival of a lined fan.

Safety Device on Continuous Reactor

WITH CONTINUOUS reactors employing several turbo-agitators on a common shaft, it frequently occurs that they are driven through a right-angled reduction gearbox. Some gear units carry an extension to the drive shaft, which may be used to drive a small positive-displacement pump. This pump can provide hydraulic pressure for controlling the action of valves handling the liquids entering or leaving the reactor. In the arrangement illustrated, pressure generated by the pump causes the valves to open. Should, for any reason, the prime mover of the agitator shaft fail or the shaft jam or seize, then the small pump automatically stops and the valves close. This ensures that materials are not introduced to the reactor unless the agitative system is in operation.

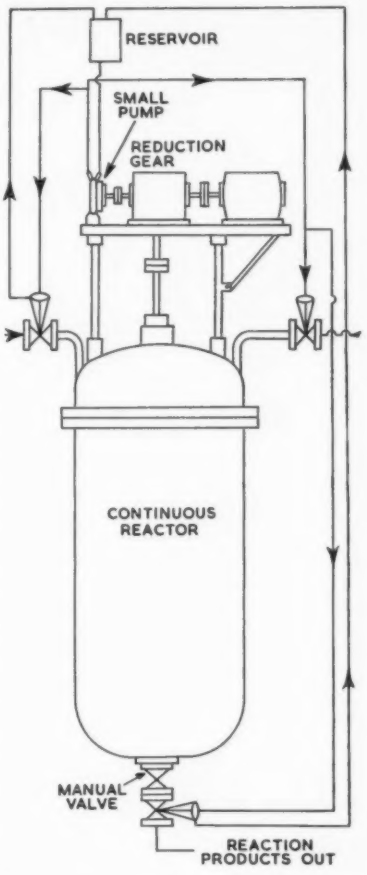
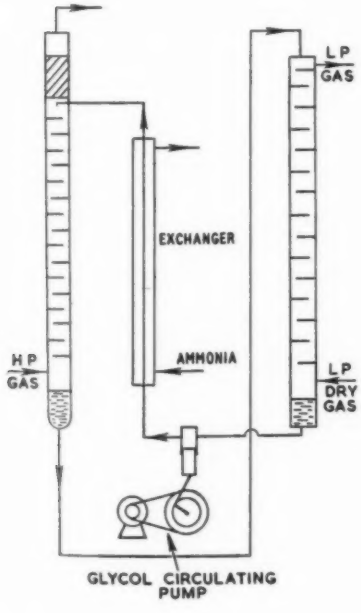
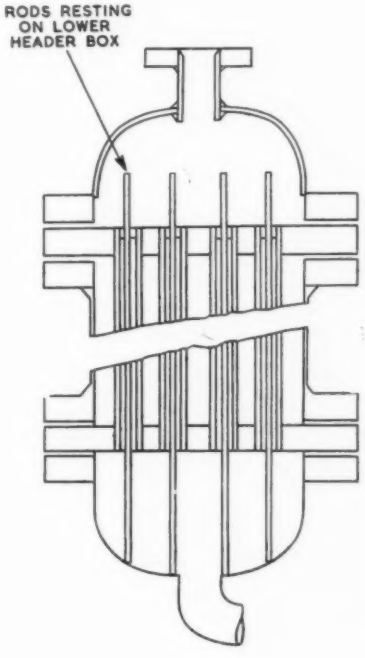


Diagram of a continuous reactor showing small pump installation.

Modification to Heat Exchanger Increases Capacity

USERS OF A low-temperature plant for separating various gases were recently faced with the problem of increasing the plant's output. Examination of the main components of the plant revealed excess capacity at all stages except the initial dehydration and cooling. A simplified diagram of this plant is illustrated. Its main features are two columns and a refrigerative system employing ammonia. High-pressure gas is fed through the first column and cooled by direct contact with a glycol solution whose temperature is approximately −43°C. The glycol leaves the column at about −30°C and is returned to a low-pressure column where is is used to scrub one of the gases separated by the main process. In this column, glycol is dehydrated but not raised significantly in temperature. It is then returned to the circulating pump before being passed through the direct expansion cooler. Examination of this part of the process revealed ample capacity, except at the cooler. Increasing the throughput of the circulating pump was impracticable, since it would have upset the hydraulics of both columns. The only measure, therefore, was to improve the film heat-transfer coefficient on the glycol side of the cooler. This was done by inserting small rods inside the tube spaces as shown in the accompanying diagram, so that they rested on the upper surface of the lower head box. Small pins were placed at intervals along the rods to ensure proper spacing of the rods within the tubes. Both the greater flow-velocity obtained and the smaller hydraulic radius produced a significant improvement in the heat-transfer rates.





Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Plastics in U.S.A.

During 1956, the total U.S. output of all types of synthetic elastomers, except vinyl elastomers, amounted to approximately 2314 million lb., an increase of 11% over the previous year. Sales amounted to 2156 million lb., valued at $588 million in 1956, compared with 2069 million lb., valued at $573 million in 1955. Of cyclic elastomers, mainly of the polybutadiene-styrene type, about 1808 million lb. were produced in 1956 compared with 1643 million lb. in 1955. 506 million lb. of acyclic elastomers (except vinyl elastomers), consisting of neoprene, butyl, silicone, isobutylene and other types, were produced in 1956 compared with 440 million lb. in 1955. Of these, neoprene was produced in the largest volume (223 million lb.), followed by butyl elastomer (166 million lb.). These figures are contained in the first report of preliminary statistics on the production and sales of various synthetic organic chemicals in 1956 to be published by the U.S. Tariff Commission.

Swedish Chemical Industry

A committee of experts, appointed in 1955 to review the likely trends in the Swedish economy during the next five-year period, recently presented its findings to the Swedish Minister of Commerce. On chemicals, it says that, although the Swedish chemicals industry since 1939 has expanded faster than Swedish industry as a whole, progress during the past five years has been slower than that of its counterpart in the majority of other European countries. As far as inorganic chemicals are concerned, the increase in production has covered domestic demand, and with organic chemicals, plastics and pharmaceuticals, it has been possible to increase exports appreciably. No petrochemicals industry has been established in Sweden. It is considered unlikely that during the next five years the Swedish chemicals industry will be able to keep pace with the rapid progress, particularly in the organic-chemical industry, abroad, unless foreign capital is forthcoming. Investments, generally, will be restricted to modernising plant. In the pharmaceuticals industry, however, expansion is likely following recent intensification of research and experimental activities. In chemical imports the committee expects an increase of only about 22% between 1955 and 1960 compared with a 99% increase between 1949 and 1955.

New Turkish Refinery

A new refinery for Turkey, having a capacity of 3,250,000 tons a year, is to be built jointly by four oil companies. They are Mobil Overseas Oil Co. Inc., a subsidiary of Socony Mobil Oil Co. Inc. (37% interest); California-Texas Corporation (34%); Royal Dutch-Shell (18%); and British Petroleum (11%). The refinery which will cost $48 million is due to come on stream in 1960. The initial installations will include a distillation unit and a catalytic reformer, and they will be designed to process Middle East and Turkish crudes for the production unit and a catalytic reformer, and fuel oil. The new plant, together with the existing Government refinery, is expected to meet all of Turkey's oil needs.

Dead Sea Chemicals

New handling machinery ordered in West Germany by the Dead Sea Potash Works for its factory at Sodom is expected to raise production from the present level of 5000 tons a month to 11,000 monthly within a year. The machinery has been ordered within the framework of the Israeli-West German Reparations Agreement. The Dead Sea bromine works have acquired patent rights in the manufacture of ethylene di-bromide, an anti-knock petrol additive, and they plan to produce 1800 tons annually.

Zirconium Purification

The National Distillers Products Corporation of America has purchased the rights, outside Australia, to operate a zirconium-purifying process elaborated by the Division of Industrial Chemistry of the Australian Commonwealth Scientific and Industrial Research Organisation. The rights were bought for $250,000.

New Polycarbonate

A new polycarbonate resin, Lexan, stated to be capable of replacing metals in many applications, is undergoing initial trials in the applied research laboratories of G.E.C. of America. The product is said to have excellent electrical characteristics, high thermal stability, low water absorption and high tensile strength.

Finnish Formaldehyde Production

The production of Finland's only formalin plant, Enso-Gutzeit Oy., is to be increased from 1500 tons to 4500 tons a year, following increased demands for the product. The orders for the new plant, it is reported, will be placed in Finland.

Italian Research

Sorin (*Societa Recerche e Impiante Nucleare*), a company formed jointly by Montecatini and Fiat, has increased its capital from 100 million to 2 milliard lire.

New Burmese Refinery

With the reopening recently of Burma Oil's refinery at Syriam, Burma is expecting to be virtually self-sufficient in petroleum products. The refinery has a daily capacity of 3500 barrels and the established refinery at Chauk an output of 3000 barrels daily.

French Natural Gas

Chemical and other factories in the Toulouse region of France received recently their first supplies of natural gas from the deposits at Lacq. The gas is being exploited by the *Societé Nationale des Petroles d'Aquitaine*, the controlling share of which is owned by the *Bureau des Recherches des Petroles*, a French Government organisation. The six wells, from which the gas is obtained, yield a combined output of 1 million cubic metres of unrefined gas a day.

Dutch Chemicals

Dutch domestic consumption of chemicals in 1956 rose by 15% over the previous year's figures, whereas exports rose by only 6%. The exports represented about 10% of the country's total exports, and were worth Fls. 950 million (£89 million) compared with Fls. 389 million (£36.3 million) in 1950. At present the exports are running at a higher level than imports.

Developments in Angola

A factory is to be built in Luanda, Portuguese West Africa, for the manufacture of nitrogenous fertiliser from the by-products of an oil refinery which is to be established there. The output will be about 70,000 tons of fertiliser a year.

Chilian Nitrate

Production costs have risen in the Chilean nitrate industry while the price abroad has dropped, and the industry is reported to be embarrassed by its inability to dispose of compensation currencies, as importers now prefer to buy freely in other markets. As a result of these difficulties, some of the smaller producers, particularly in the Iquique area, may, it is thought, be forced to close down.

Uranium Ore Treatment

A new mill with a rated capacity of 1000 tons of ore daily has just commenced production at Faraday Uranium Mines, South Africa. About $10 million has been spent on installing it.

Detergents in the U.S.A.

Monsanto of America has sold to Levers trade-mark rights and the manufacturing formula for All—Monsanto's synthetic detergent—and has granted a marketing franchise to Levers. Monsanto will continue to manufacture the products, but Lever has assumed all marketing responsibilities.

Badische Anilin

Badische Anilin and Soda-Fabrik AG. have increased their capital by DM102 million (£8½ million) to DM612 million (£52 million) in order to continue the expansion of plant for the production of dyestuffs, fertilisers, heavy chemicals and plastics.

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Book Reviews

The Chemistry of Co-ordination Compounds

Edited by J. C. Bailar
Reinhold Publishing Corp., New York; Chapman & Hall, London; 1956, 844 p.p., 148s.

THIS book, which has been compiled by Professor Bailar from his own and his students' work, is undoubtedly the most comprehensive work on co-ordination compounds in the English language. As with any book that is written by several people, there is a certain amount of overlapping, but this does not occur to a disturbing degree. The breadth of the work is illustrated by the following chapter headings: The Application of Co-ordination Compounds to Analytical Chemistry; to Natural Products; to Dyes and Pigments; to Electrodeposition; and to Water Softening. There are three chapters on Stereo-chemistry, following one on "General Isomerism of Complex Compounds". In all, there are twenty-three chapters, but in spite of this Professor Bailar says in the preface that "No attempt has been made to cover the chemistry of the co-ordination compounds completely".

Chemistry in the Service of Man, eighth edition

by Alexander Findlay
Longmans, Green & Co. Ltd., London, 1957, 326 p.p., 25s.

THE fact that this book has reached its eighth edition is enough in itself to mark its worth. It is no small service that Professor Findlay does to the lay public and the chemist in acting as a bridge between them. It is, of course, impossible to cover in detail the whole vast empire of chemistry, but the choice of material is such as to show in how many ways the work of the chemist impinges on the life of the populace.

The book, naturally, is based on the seventh edition, though much of the material appearing therein has been trimmed in order to recount some of the vast strides that have been made during the last decade. Of the new fields covered, mention may be made of drugs and antibiotics, vitamins and hormones, plant growth regulators and insecticides, and that of universal interest and concern, nuclear energy.

Professor Findlay has a very readable style, but is not afraid to use technical terms, chemical symbols and quite complex formulæ when necessary. Although, on the whole, the book is factual and accurate, in his desire to emphasise the service chemists do their fellow men he occasionally overstates his case; as, for example, the statement that "addition of auromycin to animal feed is stated to have increased the rate of growth of hogs as much as 50 per cent". In certain exceptional cases of initially very unthrifty animals this might be true. The growth rate increase due to auromycin used in the diet of normal, well-fed animals is more usually of the order of 5 to 15 per cent.

Thermal Power from Nuclear Reactors

by A. S. Thompson and O. E. Rodgers
Wiley, New York; Chapman & Hall, London; 1956, 299 p.p., 58s.

THIS book aims to cover the more important aspects of nuclear reactor design. Thus the first three chapters deal with the process of nuclear fission, critical mass calculations and reactor kinetics. Shielding and materials of construction are considered in chapters four and five, and thermal stresses, power transfer from the core and thermal power cycle efficiency are dealt with in the remaining chapters.

Those unfamiliar with the field will be grateful for the explanation of the elements of the subject given in the introduction, which allows the remainder of the book to be followed without serious difficulty. There is some unevenness in treatment as, for example, space is devoted to an elementary discussion on heat transfer which, in view of the other literature on the subject, seems unnecessary.

Nevertheless, the book has many strong points in its favour, such as the application of dimensional analysis to reactor core calculations, and the use of numerical methods for solving the criticality equations. The treatment of reactor kinetics and thermal stresses in power-producing elements are other commendable features, and it is a pity that the same standards are not evident throughout the book. It is to be hoped that in later editions the authors will extend the treatment of accepted engineering practices to other problems in nuclear reactor design.

Steels for the User, third edition

by R. T. Rolfe
Chapman & Hall, 1956, 399 p.p., 45s.

NEARLY twenty years have passed since the appearance of the first edition of this book, and this edition succeeds in the main in covering the major developments that have taken place in the intervening period. Primarily, the book deals with carbon steels and also with alloy steels for those applications where carbon steels would be unsuitable. The course taken by the author is a simple one to follow. A series of chapters deals with the mechanical properties and their assessment and the specified requirements of commercial steels. These are followed by chapters on the subjects of bright and free cutting steels and on the heat treatment of both high- and low-carbon steels. The concluding sections are more general in scope and deal with high-temperature uses of steels, weld testing and treatment, fatigue testing and a guide to the principles of selecting a steel. Such recent work as the addition of small percentages of boron steels and the production of steels by powder metallurgy has not been treated in this volume. The same remarks apply to austenitic manganese steels. Apart from these omissions, which are scarcely serious, the book is excellent and can be recommended for the bookshelf of the engineer concerned with the use of steel.

One Hundred Years of Good Company

by Bernard Newman
Ruston & Hornsby Ltd., Lincoln, 1957, 265 pp.

THIS book is more than a record of the growth of an engineering organisation whose products are known throughout the world—it is a social study showing the effects of a century of rapid progress on engineering products, men and their lives. It is written with the vividness, energy and insight characteristic of Bernard Newman, broadcaster, journalist, lecturer and author of over 90 books. Obviously, the publication has entailed much research beyond Ruston's own records, and the author has had the advantage of seeing first-hand during his travels to 60 countries some of the firm's contributions to the world's development. Much of the text is culled from dialogue recorded or obtained by interview and reminiscences, and it is illustrated with lively drawings and historical pictorial records. The book commences with the story of how Joseph Ruston acting on the suggestion of his barber in Sheffield, where he had been apprenticed to Wostenholm's, entered, in 1857, into partnership with Burton & Proctor, millwrights of Lincoln. It concludes with mention of the production by Ruston's and their associates, Davey, Paxman, of industrial gas turbines, atomic-powered generators (the company is aiming at the middle range of atomic generation) and other equipment for modern industry including welded steel vessels for chemical and oil processes, and filters. The author makes it clear that the company have always been alive to the human side of industry. Their efficiency so impressed him that he promptly invested in the company the whole of his fee for the book.

Grignard Reactions of Nonmetallic Substances

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PLANT EQUIPMENT NEWS

Oil Gasifier

An oil gasifier has been developed by Urquhart's from their oil combustion chamber. It operates instantaneously and continuously, it is said, to provide a range of hot producer gases of varying composition, and it will burn all grades of fuel oil and coal-tar fuels. The heat releases are from 1 to 30 million Btu/hr. It has been observed that combustion can be maintained at four times stoichiometric fuel-air proportions, yielding about 4% C_nH_m and methane, 4% carbon dioxide, 12-14% hydrogen and 15-18% carbon monoxide. Such compositions carry in suspension a large proportion of fine carbon up to about 5 lb. per 1000 cu. ft of gas. These can be burnt at a point remote from the primary combustion chamber with very little free carbon being carried to the chimney. **Urquhart's (1926) Ltd., 5 Wadsworth Road, Perivale, Middlesex.**

BCE 1493 for further information

Nitrogen Tank

Butterfields are now offering as standard equipment a tank for the storage of liquid nitrogen which they designed recently. Stainless steel is employed for the storage vessel and fittings and mild steel for the jacket, and insulation is achieved by the use of powder and vacuum in the space surrounding the inner vessel to minimise both radiation and conduction losses. The air pressure in the jacket is about 1/10 mm Hg, and tests conducted on a 300-gallon tank show an evaporation rate of only 0.66%, i.e., approximately two gallons per day. The rate of air leak into the jacket is said to be negligible. **W. P. Butterfield Ltd., P.O. Box 38, Shipley, Yorks.**

BCE 1494 for further information

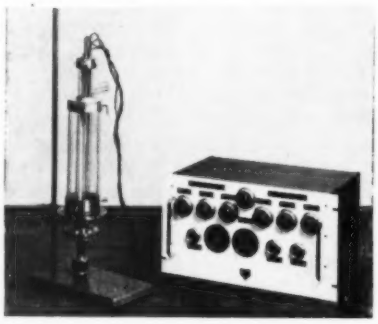
Screw Pumps

Under licence, Hamworthy are manufacturing a screw pump in a range of nineteen sizes, having capacities from 30 to 66,000 gallons per hour. The standard units are suitable for pressures up to 500 psi. The pumps are offered for use in pressure oil-fired installations, cooling and lubricating diesel engines, oil-transfer duties in refineries and in ships; and in the chemical, food and allied industries for pumping viscous liquids, fats, oils, emulsions, lyes, soaps, etc., and any liquid having reasonable lubricating properties. They are specially useful, the makers point out, for liquids in which churning has to be avoided. **Hamworthy Engineering Ltd., Poole, Dorset.**

BCE 1495 for further information

Liquid-flow Monitor

Baird & Tatlock are producing a new liquid-flow monitor for use in systems where it is necessary to maintain a rate of liquid flow to within close limits. As it operates on an electrical conductivity principle, the instrument is only suitable



for use with electrolytes. The monitor is made up of two parts—a glass unit, which is incorporated into the liquid pipeline, and the control unit, which houses the necessary relay circuits, switches, alarm lamps, etc.

The glass unit consists of a vertical cylinder closed at the lower end by an orifice plate, the orifice size being chosen so that, when the liquid is flowing normally, a small head is built up above the plate. Two platinum probes are inserted in the cylinder, one above and one below the normal liquid level, and a third probe is positioned just above the orifice plate. Connections from these probes are taken to the control unit. If the rate of liquid flow increases beyond the allowed limit, the level in the glass cylinder rises and the circuit between the probe above the orifice plate and that above the normal level is made. An alarm lamp then lights on the control unit indicating high probe covered and an alarm bell rings. By a similar process, if the rate of liquid flow decreases below the allowed limit, a low probe uncovered alarm operates. **Baird & Tatlock (London) Ltd., 14 St. Cross Street, London, E.C.1.**

BCE 1496 for further information

New Motors

Motors introduced recently by Delco include a new double-insulated appliance motor. It is a high-speed universal appliance motor having Bakelite end-frames, and it develops an output of up to $\frac{1}{8}$ h.p. A new geared motor is being made which provides an output torque of 60 oz. in. and a drive shaft speed of 100 rpm. The geared unit is built into the motor frame, and comprises a hardened steel shaft worm, which meshes with a large-diameter nylon gear. This method of speed reduction, it is said, ensures quietness of operation, low friction loss and long life. **AC-Delco, Division of General Motors Ltd., Dunstable, Beds.**

BCE 1497 for further information

SEEN AT THE INSTRUMENTS, ELECTRONICS AND AUTOMATION EXHIBITION, LONDON

Air Pressure Regulator

A new pilot-controlled air pressure regulator designed to provide precise control was featured by Norgren. Its working range is from 2 to 120 psi, and its capacity is said to be more than 200 cfm. The regulator can be located at any point in the air-line system, regardless of accessibility, and the pilot control regulator may be installed at a convenient location. Tubing of $\frac{3}{16}$-in. or $\frac{1}{4}$-in. o.d. provides the connection between pilot control regulator and pressure regulator. **C. A. Norgren Ltd., Shipston-on-Stour, Warwicks.**

BCE 1498 for further information

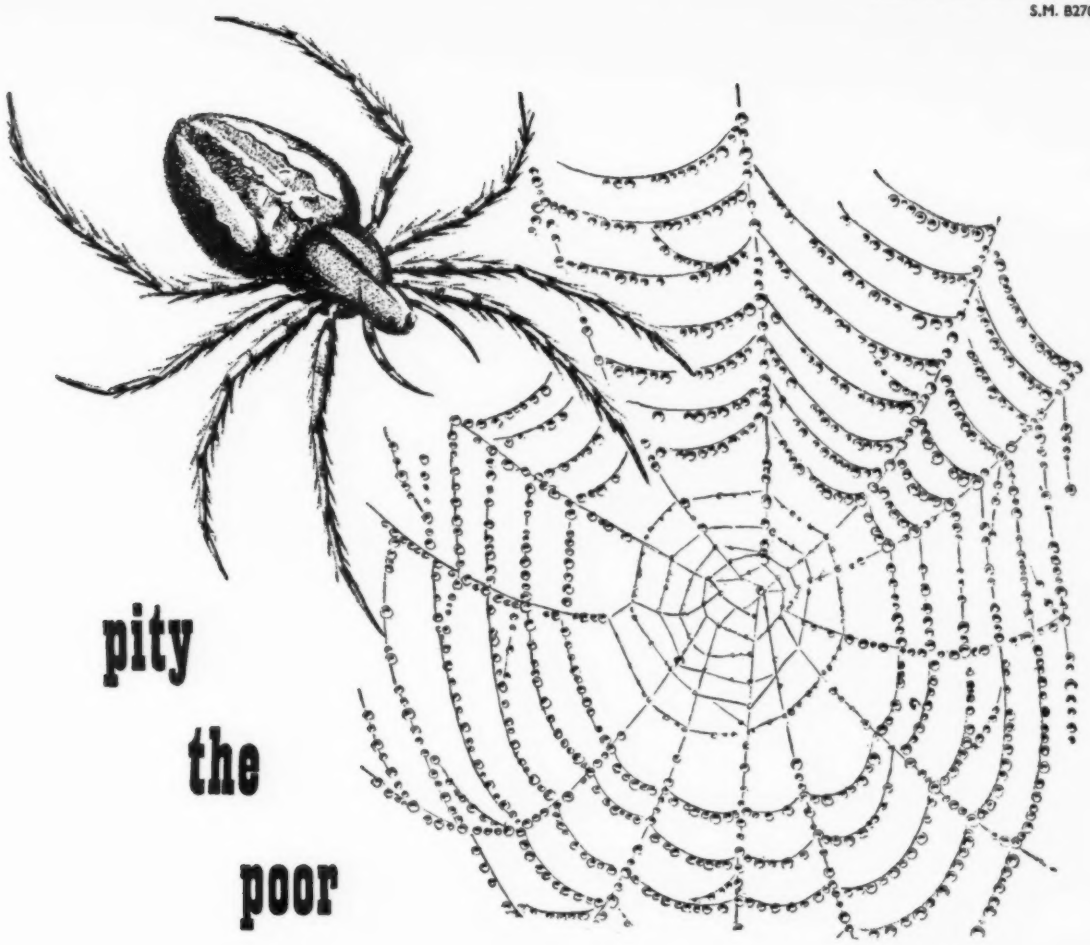
Displacement Meter

The displacement meter, type "P", shown by Leeds Meters is of the rotary piston design, and has given notably good results, the company says, over several years of proving tests. The meter is supplied with connections suitable for iron, copper and lead pipe of any specifications. It is also available with frost protection, dial-glass wiper and locking lid for sealing or padlocking. **The Leeds Meter Co. Ltd., Leeds, 12.**

BCE 1499 for further information

Air Compressors

Williams & James showed for the first time their 4-in.-stroke oil-free air compressors. The principle of the machines' operation is based on a dry compression chamber, glanded off from the crankcase, within which the other moving parts are normally lubricated. Inlet and discharge valves are made from alloy steel and are of the strip cushion type. The compressors have been specially designed to



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PLANT EQUIPMENT NEWS

eliminate shock and overheating; they are air-cooled and both twin- and four-cylinder models are fitted with a cowling to ensure a forced draught. They deliver air at a pressure of 60 psi (continuously) or 80 psi intermittently. For use with corrosive liquids and gases, the company is making reducing valves in stainless steel. They are of the same design as their established range of valves for steam and water, and are available in three sizes. **Williams & James (Engineers) Ltd., Gloucester.**

BCE 1500 for further information

Air-pollution Recorder

Fleming Radio announced that their newly-designed automatic air-pollution recorder is now in production. It takes samples every 24 or 8 hours or every hour, with a break of about 30 seconds between samples. A time mark is made on a filter-paper strip at 24-hour intervals, so enabling a check to be kept of day-to-day or hour-to-hour changes. It has been developed in collaboration with the Shirley Institute, Manchester. In the near future an automatic read-out unit will be incorporated. This is a photo-electric attachment which compares light transmitted through the sample with that passed through an adjacent clean portion of filter paper. The "difference" current of these photocells is amplified and passed to a pen recorder, which then

provides a permanent record of dirty air conditions. **Fleming Radio (Developments) Ltd., Caxton Way, Stevenage, Herts.**

BCE 1501 for further information

Level Indicators

Rotameter showed the Ekstrom liquid-level indicator fitted with magnetic-coupled switches. The instrument consists of a branch tube from the storage vessel and a separate glass gauge-tube with indicator. The branch tube, which must be of non-magnetic material, is connected to the top and bottom of the tank in the manner most convenient. It houses a float carrying a strong permanent magnet and the field of magnetic force coincides with the level of the liquid. The indicator in the glass tube is a hollow iron sphere of 1-in. diameter and having the same density as the butanol with which the gauge glass is filled. The sphere's position coincides with the liquid level in the tank. **Rotameter Manufacturing Co. Ltd., 330 Purley Way, Croydon, Surrey.**

BCE 1502 for further information

Surface Heater

A surface heater capable of achieving a temperature of 1000°C was shown by Electrothermal Engineering. The heater is flexible and, it is said, is applicable to the heating of large areas to high temperatures. It is built from a network of resistance wires insulated by interlocking high-temperature-resistant ceramic blocks. The equipment is designed to have a surface loading of up to 50 w. a square inch. **Electrothermal Engineering Ltd., 270 Neville Road, London, E.7.**

BCE 1503 for further information

Heating Cable

The new Thermocord braided heater is designed for applications requiring a heat input that cannot be met by the company's heating tapes or armoured heaters. It consists of a pure nickel-chrome heating element insulated by inorganic fibres. Two feet (61 cm.) of insulated unheated flexible lead are attached to each end of the heating section, and the whole, including the unheated leads, is covered with an external sheath of braided glass-fibre. It is designed to operate with a loading of 5 w. a linear foot and element temperatures of up to 450°C are attainable. **Electrothermal Engineering Ltd., 270 Neville Road, London, E.7.**

BCE 1504 for further information

Dissolved Oxygen Recorder

A polarographic dissolved oxygen recorder was shown by the Water Pollution Laboratory of the D.S.I.R. In the instrument, polarographic currents, reproducible over long periods and of about ten times the usual value, are given by a wide-bore dropping-mercury electrode (0.8 mm i.d.) pointing upwards at about 45° and kept at −0.5 V with respect to a pure zinc electrode in a buffer of *p*H 5.5 separated from the water under test by a sintered glass disc. Direct recording of dissolved oxygen is made possible by automatic compensation for the effect of temperature on the polarographic current. **Water Pollution Research Laboratory, Stevenage, Herts.**

BCE 1505 for further information

Rotary Vacuum Evaporator

A glass rotary vacuum evaporator was a feature shown by Towers. It is intended for the rapid evaporation of liquids at reduced temperatures, and it is particularly suitable, the makers say, for evaporating liquids containing heat-sensitive solutes, for recovering solute from dilute solutions, and for evaporating liquids which tend to froth or bump when distilled in conventional apparatus. **J. W. Towers & Co. Ltd., Widnes, Lancs.**

BCE 1506 for further information

Opacity Recorder

An apparatus for measuring the opacity of a suspension passing through a pipe was shown by Foster Instruments. It consists, in fact, of a modified smoke-density recorder and gives an alarm when the opacity reaches certain limits. It is flame-proof, and, at present, is being used in the manufacture of hydrogen peroxide. **Foster Instrument Co. Ltd., Pixmore Avenue, Letchworth, Herts.**

BCE 1507 for further information

Automatic Weighing

The application of digital transducers to control operations and of electronic counters to record quantities to any degree of accuracy within the limits of the equipment was demonstrated by E.M.I. in a system of automatic weighing which they have developed in co-operation with Western Manufacturing. The exhibit comprised a conveyor, a hopper and feed system for dry materials and a 20-lb. scale which is fitted with a graduated disc and photocells. The weight of every filled container is recorded automatically by an electric typewriter. The equipment is arranged to allow for two different feed rates, so that the initial filling is done quickly and the final stage slowly, giving a fine control of the approach to the point of equilibrium, especially with difficult materials. **E.M.I. Electronics Ltd., Hayes, Middx.**

BCE 1508 for further information

Rate Meters

Newly available rate meters were exhibited by Cass & Phillip Ltd. Originally designed to record the operating hours of elevating machinery and cranes, these instruments can be used to provide permanent records of any engineering operation. Running time is charted automatically from one minute to twelve hours. When the chart is aligned to the correct time of day, the moment of commencement, the duration of operating and in-operating periods and the number of such operations are shown. **Cass & Phillip Ltd., Mark Road, Adeyfield, Hemel Hempstead, Herts.**

BCE 1509 for further information

Plant in Glass

New equipment on the stand of Loughborough Glass included the vacuum gauge, reference VG/8, which is designed for the measurement of moderately low pressures. Absolute pressures, it is said, can be read easily at any moment. The instrument is a radical modification of the Zimmerli mercury "U" gauge. Another new exhibit was a glass pressure-relief valve intended particularly for use with glass or enamel-lined vessels to ensure continuity of the protecting lining.

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Sharples Tar Dehydration Process is operating in many countries

ONE OF THE MANY Sharples complete processing plants is the Sharples Tar Dehydration Process. At present the installed capacity is over 1,000,000 tons of dry tar per year.

The design of a tar handling plant imposes problems for every item of plant; pumps, filters, heaters and valves as well as centrifuges.

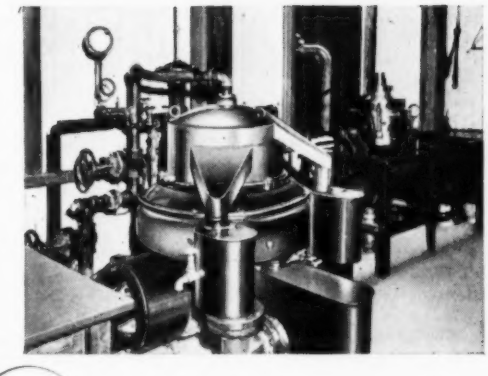
Briefly, the Sharples process consists in heating the tar emulsion to the required critical temperature, filtering out the larger particles of solid matter and then dehydrating in a Sharples DH-2 Nozljector Centrifuge. In this machine the fine solids together with the tar (in cases where the density of the tar is greater than that of water) discharge through the nozzles, whilst the water phase discharges from separate covers.

The Sharples Tar Dehydration Process is normally operated in conjunction with a continuous distillation plant, and since these units are rated on a 24 hour per day basis, the Sharples Process is designed accordingly.

This Sharples process is only one example of creative chemical engineering by the Sharples organisation.

Whether it's a matter of a complete process or a single machine every plant user can avail himself of the expert advice provided by Sharples. This is backed by extensive research facilities and full size development plants.

If you have a processing problem or a separation problem you are invited to write to the address below or 'phone Camberley 2601 and talk to Martin Trowbridge about it.



Part of a Sharples Tar Dehydration Plant. For full information on this Process write for Bulletin No. 2456M.

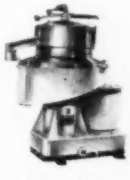
SHARPLES

Complete plants developed by Sharples include :

SHARPLES LOW LOSS VEGETABLE OIL REFINING PROCESS · SHARPLES STANDARD CAUSTIC VEGETABLE OIL REFINING PROCESS · SHARPLES CONTINUOUS SOAP PROCESS · SHARPLES WOOL GREASE RECOVERY PROCESS · SHARPLES LOW TEMPERATURE FAT RENDERING PROCESS · SHARPLES NAPTHALENE PROCESS · SHARPLES VEGETABLE OIL FOOTS PROCESS · SHARPLES TAR DEHYDRATION PROCESS · SHARPLES INSTANT COFFEE PROCESS · SHARPLES TANK-HOUSE EFFLUENT PROCESS · SHARPLES MINERAL OIL REFINING AND RECOVERY PROCESS AND OTHERS.

Super Centrifuge

D-2 Centrifuge



DG-2 Autojector

DV-2 Centrifuge

Super-D-Hydrator

Super-D-Canter

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PLANT EQUIPMENT NEWS

It consists of a glass spherical joint, the ball portion of which supports a lead weight. When the pressure in the vessel overcomes the pressure exerted by the lead weight, it lifts the ball out of the cup. Among other features shown were a new 1-gallon soxhlet apparatus and a new 4-in. diameter glass heat exchanger with a detachable jacket and a quadruple coil. **Loughborough Glass Co. Ltd., Loughborough, Leics.**

BCE 1510 for further information

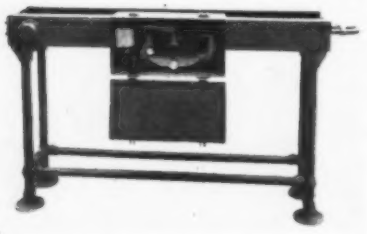
Immersion Heaters

Thermal Syndicate displayed their Vitreosil fused-silica electric immersion heaters provided with a safety earthing system which causes the circuit to break immediately if leakage occurs. **The Thermal Syndicate Ltd., P.O. Box No. 6, Wallsend, Northumberland.**

BCE 1511 for further information

Density Meter

A new continuous-weighing density meter (Mark II) was featured by Rotameter. It is suitable for higher working



pressures than the earlier model, and possesses a modified form of suspension. The principle of operation has not been altered. **Rotameter Manufacturing Co. Ltd., Purley Way, Croydon.**

BCE 1512 for further information

Reducing Valves

Blakeborough announced the availability of a new R1 reducing valve. It is a direct-acting valve, has few moving parts and is suitable for small-diameter lines handling liquids, steam or gases. The valve is offered with flat metal-to-metal seating (easily lapped for renewed tight shut-off if necessary, without special tools), or with a renewable neoprene or fluon stopper-disc. For each size of valve five interchangeable springs are available, giving a controlled pressure range of from 5 to 100 psi. **J. Blakeborough & Sons Ltd., Brighouse.**

BCE 1513 for further information

Gas Detectors

Gordon Products showed their new portable carbon-dioxide tester — an apparatus which weighs about 6 lb. and can be carried about filled with caustic potash and ready for use. Readings are shown on a round indicating dial and, it is said, can be taken without previous experience. In the company's new mono-oxygen recorder, measured samples of gas and hydrogen pass together through a miniature furnace where the oxygen combines with some of the hydrogen to form water vapour which condenses and drains into a collector. The remainder of the gas mixture passes under a measuring bell, where it is again measured, and the result is recorded. **James Gordon & Co. Ltd., Dalston Gardens, Stanmore, Middx.**

BCE 1514 for further information

The Hogas gas alarm, of which a prototype was shown, gives warning of concentrations of combustible, toxic and explosive gas-air mixtures before the danger limit is reached. Its functional element is a catalyst mass composed of several contact substances, into which is embedded a number of resistors in bridge formation. The heat arising from catalytic combustion when the gas impinges on the catalyst unbalances the resistance circuit and operates the thyratron, causing a relay to close and the alarm to be given. **Alexander Wright & Co. Ltd., 1 Westminster Palace Gardens, London, S.W.1.**

BCE 1515 for further information

Nylon Sieve

Endecotts were showing a prototype of a nylon-mesh sieve in which the mesh is attached to a metal body which itself is coated with nylon. The rims are 8 in. in diameter. **Endecotts (Filters) Ltd., 251 Kingston Road, London, S.W.19.**

BCE 1516 for further information

Heated Hose

The Isohose is a flexible hose which can be kept at the same temperature as the liquid which passes through it. The danger of solidification of material inside the hose is thus overcome, and pumping pressures can be kept down to a minimum. It consists of a metallic hose 10 or 20 ft in length and 1 to 4 in. in bore, fitted with an electric heating circuit. A high-temperature lagging is fitted over the heating circuit, and the lagging is covered by a canvas or weatherproof outer. Temperatures of 400-450°F can be attained with it. **Isopad Ltd., Barnet By-Pass, Boreham Wood, Herts.**

BCE 1517 for further information

Process Timer

The new process timer, type N237, shown by Airmec, has a working range of from 1 to 100 seconds. An automatic resetting device is built into the instrument, and two timers may be operated back-to-back so that when the timed period of No. 1 ends it starts the timed period of No. 2. The scale calibration accuracy is said to be better than ±3%. The company's new temperature control unit, N.241, operates over the temperature range −70°C to +600°C, and its control is effected by a heavy-duty output relay. The sensitive element, a platinum resistance, is of very small dimensions, robust and stable. **Airmec Ltd., High Wycombe, Bucks.**

BCE 1518 for further information

Pilot Valves

Hunt & Mitton showed a range of Sicol Valvair pilot valves for which they are the sole licensees and manufacturers for Europe and the British Commonwealth (except Canada). The valves are suitable for use with air, oil, water, inert gas or vacuum. Standardisation in their design permits any one of eight control assemblies to be inserted on the same model. **Hunt & Mitton Ltd., Oozells Street North, Birmingham, 1.**

BCE 1519 for further information

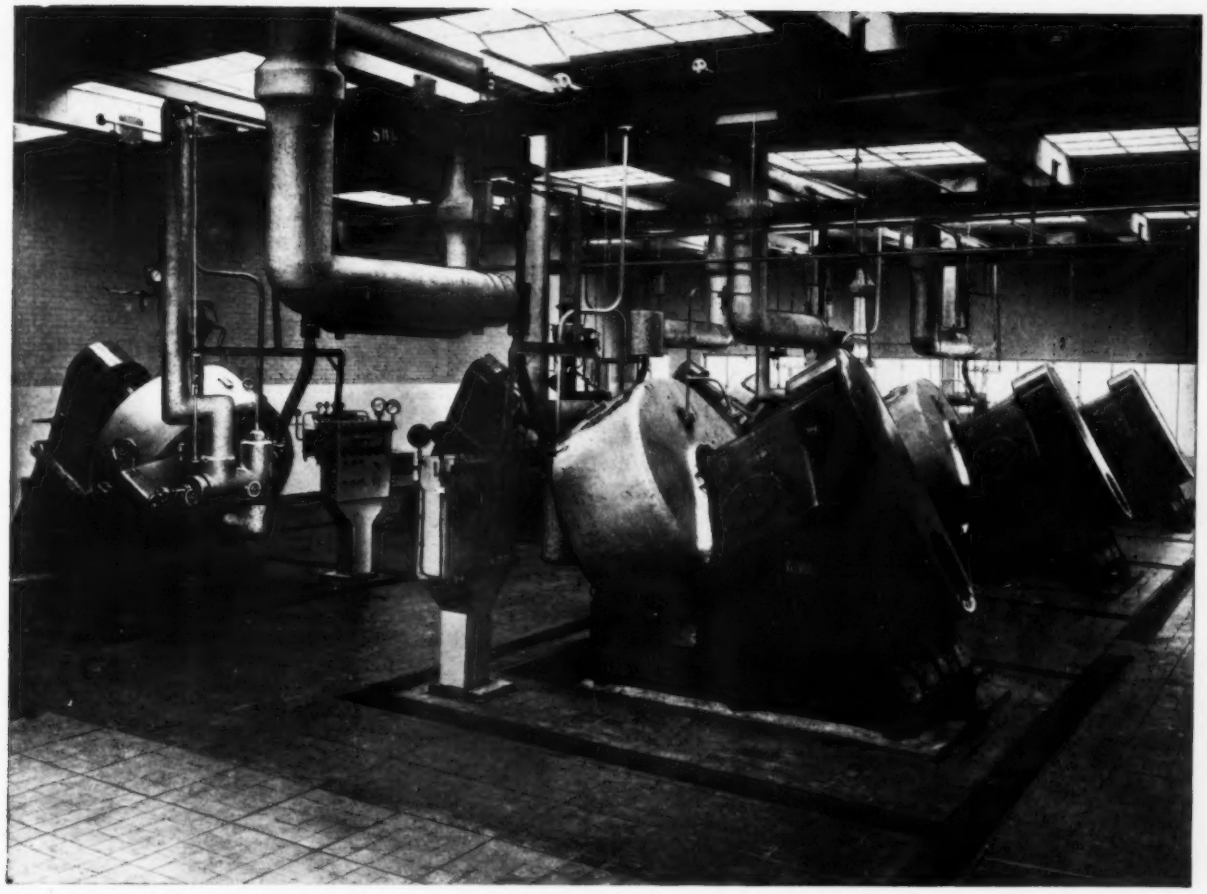
Process Control Instruments

Lancashire Dynamo showed a new completely transistorised capacity-operated level control. It is said to be suitable for a wide range of fluids, and of granular substances and powders, and

to be simple to install. Much of the circuit is housed in the probe head, and only two connections and an earth are required between the head and the main unit containing the electromechanical relays and the power supply. The main control unit can be placed at any desired distance from the head. Various forms of the main unit are available to suit high-level, low-level and multi-level operation. The company also showed a new photo-electric smoke densitometer and alarm. **Lancashire Dynamo Electronic Products Ltd., Rugeley, Staffs.**

BCE 1520 for further information

A new series of Swartwout Autronic electronic controls for process and power instrumentation was featured by Elliott, and the makers claim that it is the first miniature, all-electric, control system available for process and power instrumentation. In the system, the process variables are converted into small voltages by primary sensing elements. These voltages are transmitted to the centrally located Autronic controller, where they are continuously modulated electronically. The resulting voltage is transmitted electrically to the final element or transducer. The controller can be located at any convenient point. Autronic temperature transmitters, which are included



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is not accidental—it results from patient and carefully planned research and calls for exceptionally skilled manufacturing techniques.

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Conditions are far from easy, and the materials are handled at extremely low temperatures with explosion risks.

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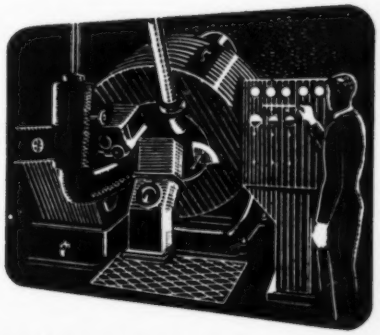

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PLANT EQUIPMENT NEWS

in the series, consist of two units: a thermometer element made of platinum wire wound on a ceramic core and hermetically sealed in an Inconel tube, and a thermometer adapter which converts resistance changes of the thermometer element to proportional signal voltages. **Elliott Brothers (London) Ltd., Century Works, Lewisham, London, S.E.13.**

BCE 1521 for further information

The latest addition to the Sunvic range of miniature panel instruments—the Sunvic miniature recorder, model 24 series—was on show. The recorder has three receiving elements, which record measured value and indicate continuously the desired value and valve position. It is adapted to receive Sunvic plug-in controllers, and is provided with a precision regulator for desired-value setting and a switch for changing to manual operation. It can easily be converted for use as a slave control station in a cascaded system. **Sunvic Controls Ltd., No. 1 Factory, Temple Fields, Harlow, Essex.**

BCE 1522 for further information

Evershed's new Mark IV process controller is completely electronic and contains no moving parts. The three control terms (proportional, integral and derivative) are generated separately, and they are therefore free from interaction. The calibrated value of each term thus operates precisely at all settings. *In situ* testing may be undertaken without disturbing the plant under control. **Evershed & Vignoles Ltd., London, W4.**

BCE 1523 for further information

The new M/54 Consotrol recorder/controller was shown by Foxboro-Yoxall. The controller (when mounted at the rear of the recorder) can be removed completely from the panel whilst the transfer switch is in the "seal" position. The unit slides into a sheet-steel housing secured to the panel, to which are

attached all the external connections. Another instrument shown was the Foxboro new magnetic flow meter, which is being manufactured under licence. It comprises a transmitter and a Dynalog flow receiver. The transmitter consists of a stainless-steel tube through which the liquid passes, an electrical-insulating liner, an electro-magnet which induces a magnetic field across the tube, and two metallic electrodes flush with the inside surface of the tube. Transmitters are made in line-sizes of from 2 to 8 in., suitable for flow rates of from 0-2500 gpm to 0-40,000 gpm. **Foxboro-Yoxall Ltd., Lombard Road, London, S.W.19.**

BCE 1524 for further information

Kelvin & Hughes were showing a transistor-type indicating controller, Mark 4, having a proportional action. Performance claimed for it includes a control of sensitivity better than 0.1% of full-scale deflection and true indication of up to 20% of f.s.d. above the set point. Its principal use is for the measurement and control of temperature when employed in

conjunction with a thermocouple or resistance thermometer. Other controllers in the range include instruments with a two- or three-position action. **Kelvin & Hughes (Industrial) Ltd., 2 Caxton Street, London, S.W.1.**

BCE 1525 for further ifnormation

Automatic flow-control equipment was being offered by Fischer & Porter. They supply the complete equipment except the air-motor valve. It was announced that at their factory at Harrow the company are tooling-up for the manufacture of a new pneumatic transmitter recorder and controller. New to Britain is their standard percentage of maximum flow scales, which may be used with their Flowrator flow indicators. They are applicable, it is said, to almost any liquid. **Fischer & Porter Ltd., 205 Station Road, Harrow, Middx.**

BCE 1526 for further information

Oil-mist Separator

A feature of the new self-adjusting separator for removing oil mist from compressed air or gas, shown by Keith Blackman, is that its annular nozzle is automatically adjusted to suit the volume passing. A constant velocity of flow is therefore maintained, and this, it is said, allows the degree of separation to be substantially the same at both high and low flow rates. At present the separator is being manufactured in two sizes—for volumes of up to 900 cu. ft an hour and of from 1000 to 5500 cu. ft an hour. Both sizes are suitable for pressures up to 10 psi and cause a pressure loss of

about 7 in. w.g. **Keith Blackman Ltd., Mill Mead Road, London, N.17.**

BCE 1527 for further information

Other Items of Interest

Elga Products showed their new Elgastat Major deioniser. This is a self-contained apparatus and has an output of up to 7 gallons (35 litres) of cold purified water per hour continuously. Its product is described as conductivity water. **Elga Products Ltd., Railway Place, London, S.W.19.**

BCE 1528 for further information

The latest designs in their range of instrument cubicles were displayed by **New Western (Engineering) Ltd., Meadow Lane, Leeds, 11.**

BCE 1529 for further information

SEEN AT THE B.I.F., BIRMINGHAM

Plastic Piping

Plastex compression joints were offered as a simple and speedy means of joining polythene tubing of normal gauge. A taper union is incorporated in the design of the cupped ferrule used in the fitting, and this permits the joint to be made and re-made at will. The fitting is said to be suitable for permanent or temporary installations. **Compression Joints Ltd., Tyburn Road, Birmingham, 24.**

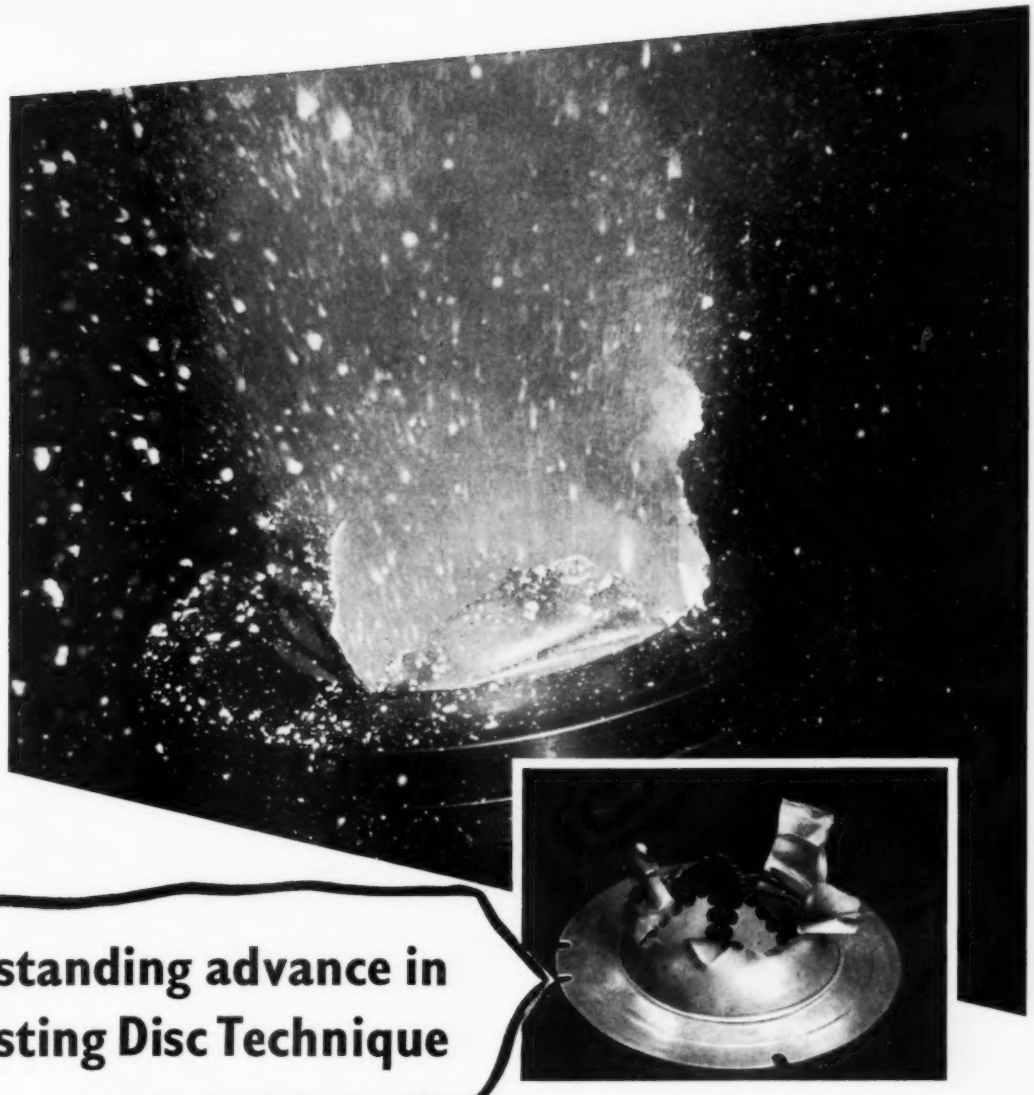
BCE 1530 for further information

A range of Deltathene high-tensile polythene plastic piping made from Delta Metal's extruded polythene was shown by the wholesale distributors: **F. H. Bourner & Co. (Engineers) Ltd., Manor Royal, Crawley, Sussex.**

BCE 1531 for further information

A number of plastic pipe-line materials were shown for the first time by Prodorite. The claim was made that they were all corrosion-resistant, light and strong. They included Durapipe K, which is a styrene-butadiene-acrylonitrile compound, having great impact strength. It is non-toxic and imparts no taint or odour to process liquids, and it is available in three pressure ratings—light, normal and heavy. Durapipe N is a polyamide material of the Nylon 6 type. Durapipe Z, a new

BCE 1446 for further information



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All D.C.L. Bursting Discs incorporate a PATENTED INTERLOCKING SYSTEM which POSITIVELY ensures that only the correct disc can be used.

D.C.L. Discs are domed by the application of pressure approaching the bursting pressure—a PATENTED FEATURE which ensures that the bursting discs last longer service.

Each D.C.L. Disc is individually designed and full details of the proposed operating conditions should therefore accompany an enquiry. A Questionnaire is available on request.

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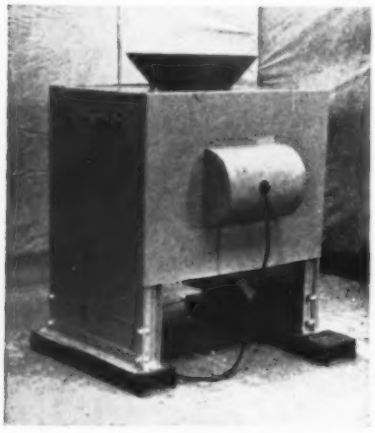
PLANT EQUIPMENT NEWS

low-pressure polythene, was also being offered. A recent addition to the rigid P.V.C. range is Vykem high-impact P.V.C. It is similar in mechanical properties to normal P.V.C., except that it possesses a high degree of resistance to impact and shock. **Prodorite Ltd., Eagle Works, Wednesbury, Staffs.**

BCE 1532 for further information

Magnetic Filter

The Boxmag filter is an electromagnetic filter designed for the extraction of iron contamination such as fine iron and oxides from powder, granular and liquid materials in a free-flowing or sticky state.



A magnetic field of great intensity is induced across steel grids which are arranged so that the material being treated passes freely through them, yet contacts the edges of the grid. To these any extracted ferrous contamination adheres, and it is then bled off into a chute. **Electromagnets Ltd., Boxmag Works, Bond Street, Hockley, Birmingham, 19.**

BCE 1533 for further information

Electrically-operated Valves

Saunders have extended their range of electrically-actuated diaphragm valves to cover smaller sizes—from ½ in. to 4 in. Actuator 1F is used for sizes ½ in. to 2 in., and actuator 12B for the other sizes in the new range. **Saunders Valve Co. Ltd., Cwmbran, Mon.**

BCE 1534 for further information

Corrosion-resisting Trucks

New designs of resin-bonded glass-fibre box trucks were shown by **Bakelite Ltd., 12 Grosvenor Gardens, London, S.W.1.**

BCE 1535 for further information

Rotary-action Screen

A rotary-action screen 60 in. wide and 140 in. long, having a rotary action at the drive end and a lineal action at the discharge end, was shown. If necessary, up to six separations can be made at once with the screen. Also shown was the Waytrol type 118 constant-weight feeder fitted with a new photo-electric cell operation which gives it an accuracy of ±1%. **Lockers (Engineers) Ltd., Church Street, Warrington.**

BCE 1536 for further information

Synthetic Rubber Products

Duthane, a new type of synthetic rubber based on polyurethane, was shown in the form of a range of moulded products. They included underflow nozzle linings used in wet cyclones for ore classification in the gold and base metal industries. The nozzles have to withstand severe abrasion, particularly with quartzite gold-bearing ore. **Dunlop Rubber Co. Ltd., Fort Dunlop, Erdington, Birmingham, 24.**

BCE 1537 for further information

Air Compressor

Shown for the first time was the 600-cfm Hydrovane air compressor manufactured under licence by Whittaker Hall. **Alfred Bullows & Sons Ltd., Long Street, Walsall.**

BCE 1538 for further information

Pipe-line Cooler

A new pipe-line cooler for use as an after-cooler in compressed-air lines was featured by Spiral Tubes. It consists of a nest of tubes inside a pipe shell. Cooling water enters the unit at one end and leaves at the opposite end. **The Spiral Tube & Components Ltd., Osmaston Park Road, Derby.**

BCE 1539 for further information

Titanium Applications

The Metals Division of I.C.I. showed titanium and titanium alloys applied to chemical engineering. Exhibits included titanium-lined vessels and piping. **Imperial Chemical Industries Ltd., Kynoch Works, Birmingham, 6.**

BCE 1540 for further information

Vibrating Screen

The Parkwood screen is now being made available with a vibrating mechanism to increase its capacity. The semi-cylindrical screen is mounted on rubber blocks within a cast-iron body. Vibration is applied longitudinally, and the liquor falls through the open bottom, the solids being swept over the front by slow-moving brushes. This machine is specially suitable for liquors containing small proportions of fibrous matter. **The Longwood Engineering Co. Ltd., Parkwood Mills, Huddersfield.**

BCE 1541 for further information

Tannating Liquid

Plus-gas formula "E" external metal treatment is a new tannating process for the preparation of rusted surfaces prior to painting. The tannate-gamma-ferric oxide complex formed by reaction of the tannins with the oxides on the metal surfaces creates, it is said, an insoluble, corrosion-resisting film. **Plus Gas Co. Ltd., 1 Hay Hill, London, W.1.**

BCE 1542 for further information

New Publications

Norgren have issued a four-page leaflet describing the use of their air filters and pressure regulators in pneumatic instrumentation systems. C. A. Norgren Ltd., Shipston-on-Stour, Warwicks.

BCE 1543 for further information

High Duty Alloys have issued a 37-page spiral-backed booklet containing technical data for Magnuminium alloy and magnesium, zirconium and thorium-containing alloys, to help designers to select the most suitable product for particular requirements. High Duty Alloys Ltd., Slough, Bucks.

BCE 1544 for further information

The latest issue of *Plastics Review* contains notes on the use of plastics in the chemical industry. They are illustrated with pictures of reinforced-resin wet-goods trucks and a chemical valve fabricated from components moulded or extruded in Bakelite polythene. Bakelite Ltd., 12 Hobart Place, London, S.W.1.

BCE 1545 for further information

"Ultra Clean Air" is the title of a new four-page leaflet describing Fleetway paper air-filters. Sturtevant Engineering Co. Ltd., Southern House, Cannon Street, London, E.C.4.

BCE 1546 for further information

Two new leaflets illustrating B.K.L. Alloys' range of welding fittings have just been issued. They deal, respectively, with fittings made to American standard specifications for the petroleum and petrochemical industries and carbon steel fittings made to British Standard tube sizes. B.K.L. Alloys Ltd., Birmingham Factory Centre, Kings Norton, Birmingham, 30.

BCE 1547 for further information

An up-to-date list of all the industrial films available on free issue from the Central Film Library of the C.O.I. has recently been published by the Central Office of Infomation, Norgeby House, 83 Baker Street, London, W.1.

BCE 1548 for further information

Lafarge have just published a completely re-written booklet on refractory concrete and they have also issued a brochure giving the names and addresses of suppliers of their range of refractory and insulating products. Lafarge Aluminous Cement Co. Ltd., 73 Brook Street, London, W.1.

BCE 1549 for further information

Publication No. 1523, recently issued by Rhodes, Brydon & Youatt, deals with their Mopump range of condensate-return sets. It is a four-page illustrated leaflet in colour. Rhodes, Brydon & Youatt Ltd., Waterloo Engineering Works, Gorsey Mount Street, Stockport.

BCE 1550 for further information

A four-page illustrated brochure devoted to the uses and advantages of drum heaters is the latest publication to be issued by Stabilag Co. Ltd., Mark Road, Hemel Hempstead.

BCE 1551 for further information

space reserved for a teddington bellows

Movement of pipe work under modern high-pressure and high-temperature conditions is absorbed efficiently by Teddington Bellows Expansion Joints. Teddington Bellows are of highest quality stainless steel, flawlessly butt-welded to ensure perfect uniformity of wall for maximum durability.
Normal production ranges from 1″ to 7′ diameters and larger sizes can be made.
Your expansion problem can be solved by our experienced engineers who are always available for consultation and recommendation.

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Month's News in Brief

Lobitos Oil Fields, Ellesmere Port, have recently inaugurated a new platforming unit. Our illustration shows, left to right, heaters and attendant stack; reactors; stripper column and, behind, gas treater; high-pressure reaction-product separator; and hydrogen compressors.

One of the most modern and best-equipped factories of its type in the country has just been completed at St. Helens, Lancashire, by Ashdowns Ltd., a subsidiary of Pilkington Bros. Ltd., to enable the company to devote itself to the latest developments in the fast-expanding plastics industry. The 120,000-sq.-ft factory contains more than £250,000 worth of equipment, including £100,000 worth of new plant acquired during the past twelve months. Its opening marks a complete reorganisation of the company's production policy. The Pilkington group has also announced the recent purchase of the share capital of Mendip Chemical Engineering Ltd., Ashford, Middlesex. This company, built up over the past three years by J. C. Newson and W. T. Nunn, will continue to design and manufacture prototypes, while production quantities will be handled by Ashdowns Ltd. at St. Helens.

The National Industrial Fuel Efficiency Service has announced that refresher courses for works managers and plant engineers will take place during September next. That at the University of Leeds begins on Monday, September 16, concluding on Friday, September 20. Copies of the programme and registration forms may be obtained from the Secretary: Mr. F. W. Anderson, National Industrial Fuel Efficiency Service, St. Paul's House, 20/22 St. Paul's Street, Leeds, 1.

The Oxford course opens at The Clarendon Laboratory on Monday, September 23, closing on Friday, September 27. Copies of the programme and registration forms may be obtained from the Secretary: Mr. E. S. Watkin, National Industrial Fuel Efficiency Service, Ailsa House, 181 King's Road, Reading, Berks.

British Oxygen Gases Ltd. are to build a new oxygen-compressing station at Mosley Road, Stretford, to meet the increased demands for the gas in the Manchester area. B.O.G. also announce that, owing to the rapid expansion of industries in the north-east, they are building a new factory at Grangetown, Middlesbrough, at an estimated cost of £1¾ million. The new plant will produce compressed and liquid oxygen and liquid and tonnage nitrogen (which will be fed, after purification, by pipe-line to the I.C.I. factory at Wilton).

An important lead towards solving the problem of the national shortage of trained scientists and technologists is to be made by the pharmaceutical manufacturers, Pfizer Ltd. Under two new training schemes announced recently, the company will each year assist ten students of school age to attend a full-time course at a technical college, and thereafter to study either at a university or college of technology or enter the company's laboratories as technicians.

Q.V.F. Ltd. held an informal reception recently to mark the completion of the first stage of their development programme (new premises totalling 60,000 sq. ft) at Fenton. Mr. B. H. Turpin, managing director of Q.V.F. Ltd., stated that the second stage is proceeding with the equipping of a further 30,000 sq. ft of floor space for carrying stocks of glassware.

The twenty-sixth Exposition of Chemical Industries will return to New York after an absence of six years. It is to be staged for the first time in the Coliseum during the week of December 2 to 6. Some 500 exhibitors are planning what is reported as "the greatest and most comprehensive array of chemical products and chemical process equipment since the exposition was established 42 years ago."

G. & J. Weir Ltd. announce that they have acquired a controlling interest in the Canadian firm of Peacock Bros. Ltd., of Ville La Salle, P.Q. Peacock Bros. have been established for over sixty years, during much of which time they have represented Weir and Drysdale, as well as other important British and American firms. The control of this business will strengthen Weir connections in Canada.

It is announced that the Borough Polytechnic, London, S.E.1, is now recognised by the (Hives) National Council for Technological Awards as a centre for courses leading to the diploma in technology. Approval has been given to a four-year sandwich course in chemical technology with specialisation in one of three branches: (i) plastics and high polymers; (ii) paints and surface coatings; and (iii) oils, fats and detergents.

Tube Investments Ltd. announces the formation of a new subsidiary company, TI Nuclear Engineering Ltd., with head office at The Adelphi, London, W.C.2, to assist its operating companies which are concerned with activities in the atomic energy industry in the promotion of business at home and abroad.

We regret that in the June issue (p. 342) the name of **Beldam** Asbestos Co. Ltd., of Lascar House, Hounslow, Middlesex, was incorrectly spelt.

Dr. Hassett, author of the series of articles on "The Application of Automatic Process Control to Chemical Engineering", has brought to our notice inaccuracies which appeared in Part 2 of his series (June issue, p. 313). These are as follows:

p. 314, Equation (3):

$$dt = -\frac{C}{AU}\frac{d\theta}{\theta} = -L.\frac{d\theta}{\theta}$$

p. 315, Equation (9):

$$\frac{d\theta}{(N-\theta/L)} = dt.$$

Final paragraph (p. 315), first line should read: ". . . when the time t exceeds three times the time constant L, the thermometer reading lags . . ."

Forthcoming Events

June 24. *Congress on "Modern Analytical Chemistry" organised by the Scottish Section of The Society for Analytical Chemistry:* At St. Andrews University, Glasgow, until June 28.

July 5. *One-day conference on "The Supply of Scientists and Technologists for Industry" under the auspices of The British Association for the Advancement of Science:* At Leeds University, Leeds.

July 10. *Joint conference on "Thermodynamics and Transport of Fluids":* At Institution of Mechanical Engineers, London, until July 12.

July 10. *International British Plastics Exhibition and Convention:* At Grand and National Halls, Olympia, London, until July 20.

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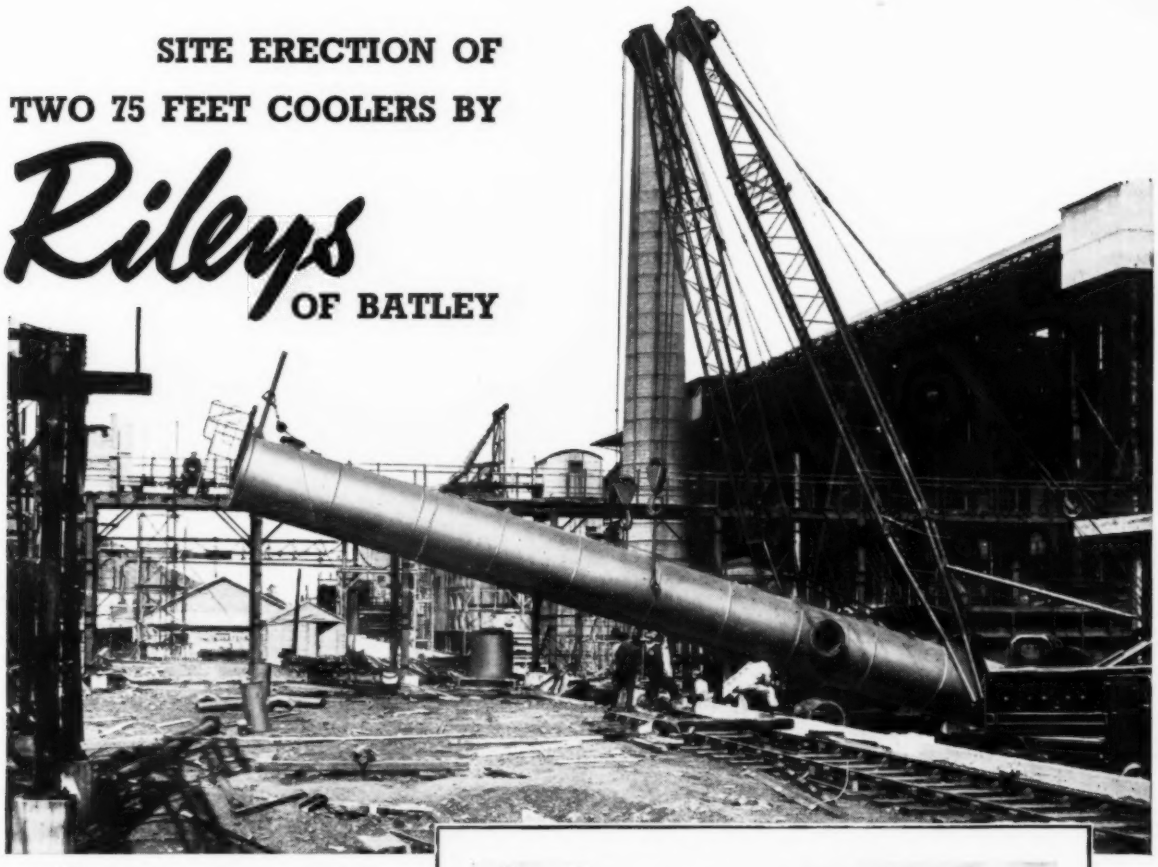

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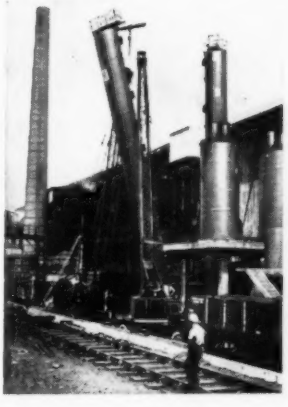

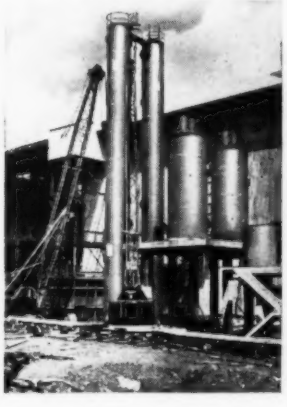

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July 11. *Physical Society Conference on "Materials for Nuclear Engineering":* At Associated Electrical Industries Ltd., Aldermaston, Berkshire, until July 12.

July 13. *A week-end conference on "Careers for Girls in Engineering" organised by the Women's Engineering Society:* At City of Coventry Training College, Coventry, until July 14.

July 17. *Nuclear Physics Conference under the auspices of The Physical Society:* At Physical Laboratories of Manchester University, Manchester, until July 18.

July 26. *Joint meeting and one-day conference of the Food Law Institute of the United States, the Food Group of the Society of Chemical Industry, the Society for Analytical Chemistry and the Association of Public Analysts of Great Britain on "Control of Chemical Additives in Food":* At The Royal Institution, London.

Overseas

June 24. *The Eleventh International Congress on The Organisation of Science:* At Paris, France, until June 28.

June 28. *International Trade Fair:* At Trieste, Yugoslavia, until July 8.

June 30. *Annual Assembly of the International Institute of Welding:* At Essen, Germany, until July 6.

July 18. *Sixteenth International Congress of Pure and Applied Chemistry:* At Paris, France, until July 24.

People in the News

Sir George Nelson.

W. R. Brown.

Sir George H. Nelson, chairman of The English Electric Co. Ltd., received the honorary degree of Doctor of Laws at the Convocation at the University of Manchester on May 13. His services to industry and his work in the field of technical education are widespread. A Fellow of the City and Guilds Technical College, London, a knighthood was conferred on Sir George in 1943 in recognition of the public work he had continually undertaken. He is a past president of the Institution of Electrical Engineers and a former vice-president of the Institution of Mechanical Engineers, of which he was installed president on April 26, 1957. For two years, from 1943 to 1945, he was president of the Federation of British Industries and he has been a member of the Federation's Grand Council for the past twelve years. He is a Governor and an Honorary Fellow of Queen Mary College (University of London) and an Honorary Fellow and a member of the governing body of the Imperial College of Science and Technology. In the 1955 Birthday Honours he was created a Baronet.

The Power-Gas Corporation, of Stockton-on-Tees, have announced the appointment of **Major W. R. Brown** as chairman and managing director in succession to the late **Dr. E. N. Rambush**, whose death occurred on May 15, 1957.

Viscount Chandos was re-appointed president of the British Electrical Development Association at the Association's recent annual general meeting. **Sir Josiah Eccles**, deputy chairman (Operation), Central Electricity Authority, and **Mr. Victor W. Dale**, former director and secretary of E.D.A., were appointed vice-presidents, and **Lord Beveridge** and **Captain J. M. Donaldson** were re-appointed vice-presidents. At the first meeting of the new council of the Association, **Mr. W. S. Lewis**, chairman of the Midlands Electricity Board, was elected chairman for the year 1957/58, and **Mr. W. N. C. Clinch**, controller, Eastern Division, Central Electricity Authority, was elected vice-chairman.

British Titan Products Co. Ltd. have announced the following: **Mr. R. W. Ancrum**, formerly technical director, left the service of the company on April 30, 1957, to take up another appointment; **Mr. S. G. Tinsley**, formerly general sales manager, is appointed technical controller and will be responsible for the company's technical activities, including production; **Dr. P. A. Lintern**, formerly production manager, is appointed overseas controller; **Dr. A. Bowman**, formerly export sales manager, will take up special duties in the technical organisation of the company at Billingham; **Mr. L. W. Robson**, formerly home sales manager, is appointed general sales manager; and **Mr. C. N. Taylor**, formerly London sales representative, is appointed assistant to the general sales manager and will shortly move to the company's head office in York.

Captain G. P. Claridge has relinquished his position as chief executive of the Council of British Manufacturers of Petroleum Equipment for reasons of health, and as from May 1, **Mr. G. V. Sims** has accepted the post of director of the Council, having relinquished the chairmanship. As a past chairman of the Council, **Mr. E. F. E. Howard** (Hayward Tyler & Co. Ltd.) has been asked to act temporarily as chairman until **Mr. G. H. Thorne** (Dawnays Ltd.), vice-chairman (and chairman-designate), can take over.

Further senior management appointments announced by Shell Chemical Co. Ltd. are: **Mr. A. D. Buckland-Nicks** as industrial field sales controller, a post in which he will supervise the operation of all the sales divisions and will act, when necessary, as deputy for **Mr. P. J. March**, the new marketing manager (industrial).

Air Control Installations Ltd. have announced that **Mr. G. E. Clifford** has been appointed technical director and that **Mr. H. C. S. Brand** has been appointed works director. Air Control, which had its first offices above a small shop at Ruislip, and is now one of Great Britain's leading manufacturers of fans, dust collectors and other air treatment plant, celebrated 21 years of progress with an "Open Day" on May 30 last.

Mr. H. U. Cunningham, who has been managing director of Scottish Agricultural Industries Ltd. since 1947, will retire from the service of the company on September 30, 1957. **Mr. E. P. Hudson**, joint assistant managing director, will succeed Mr. Cunningham as from October 1, 1957.

Dr. F. A. Tatford, chief purchasing officer of the United Kingdom Atomic Energy Authority, is being appointed director of contracts in succession to **Mr. R. A. Browning**, who is retiring in the near future. Dr. Tatford's office will be at 1 Richmond Terrace, Whitehall, London, S.W.1.

Thomas Hedley & Co. Ltd. announce the appointment of **Mr. D. E. Roberts** to be a division manager in the company's buying department. He will be responsible primarily for the buying of chemicals, chemical plant and equipment.

At the recent annual general meeting of the British Seamless Rubber and Plastics Manufacturers' Association, the following officers were re-elected for 1957: chairman: **Mr. S. D. Sutton**, Veedip Ltd.; and vice-chairman: **Mr. A. R. Reid**, London Rubber Co.

Mr. John W. Throckmorton, vice-president of Petrol-Chem Development Co. of New York, is at present visiting Europe, touring refineries and chemical plants. While in Europe, Mr. Throckmorton will be visiting his licensees for Great Britain and the Commonwealth, Birwelco Ltd., of Birmingham, and will also be visiting Germany in company with Birwelco's general manager, **Mr. R. G. Lewis.**

Mr. F. W. Combie, managing director of Megator Pumps & Compressors Ltd., left Southampton on May 16 on a fact-finding tour of the United States. His aim during the tour is to investigate the American industrial market as a prelude to a Megator export drive.

Obituary

Sir Alfred Herbert, for more than half a century a leading figure in industry, died on May 26 at the age of 90. Born on September 5, 1866, the son of William Herbert, of Leicester, he was educated at the Stoneygate House School. He was apprenticed to engineering and, while still a young man, created his own firm at Coventry, Alfred Herbert Ltd. It became one of the most important units in the United Kingdom machine tool industry, with large subsidiary interests in Argentina, France, Italy, Australia and India. Although its shares were widely held, his own holdings made him one of the richest men in the country. He was made a K.B.E. in 1917 and held the Orders of the Legion of Honour, Stanislas of Russia and Leopold of Belgium. In 1933 he was created an Honorary Freeman of Coventry.

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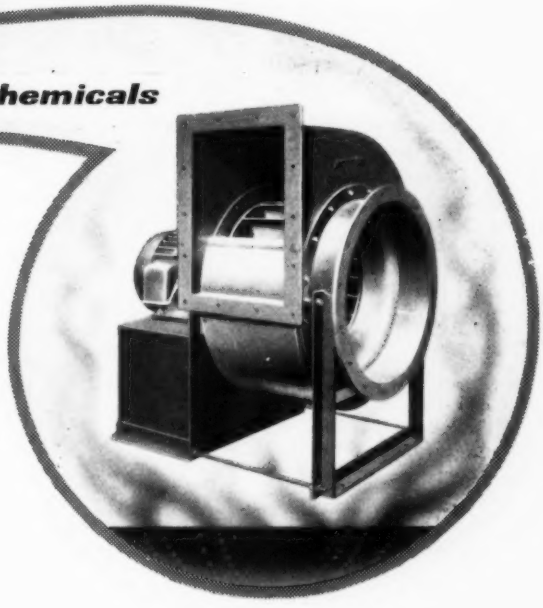

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